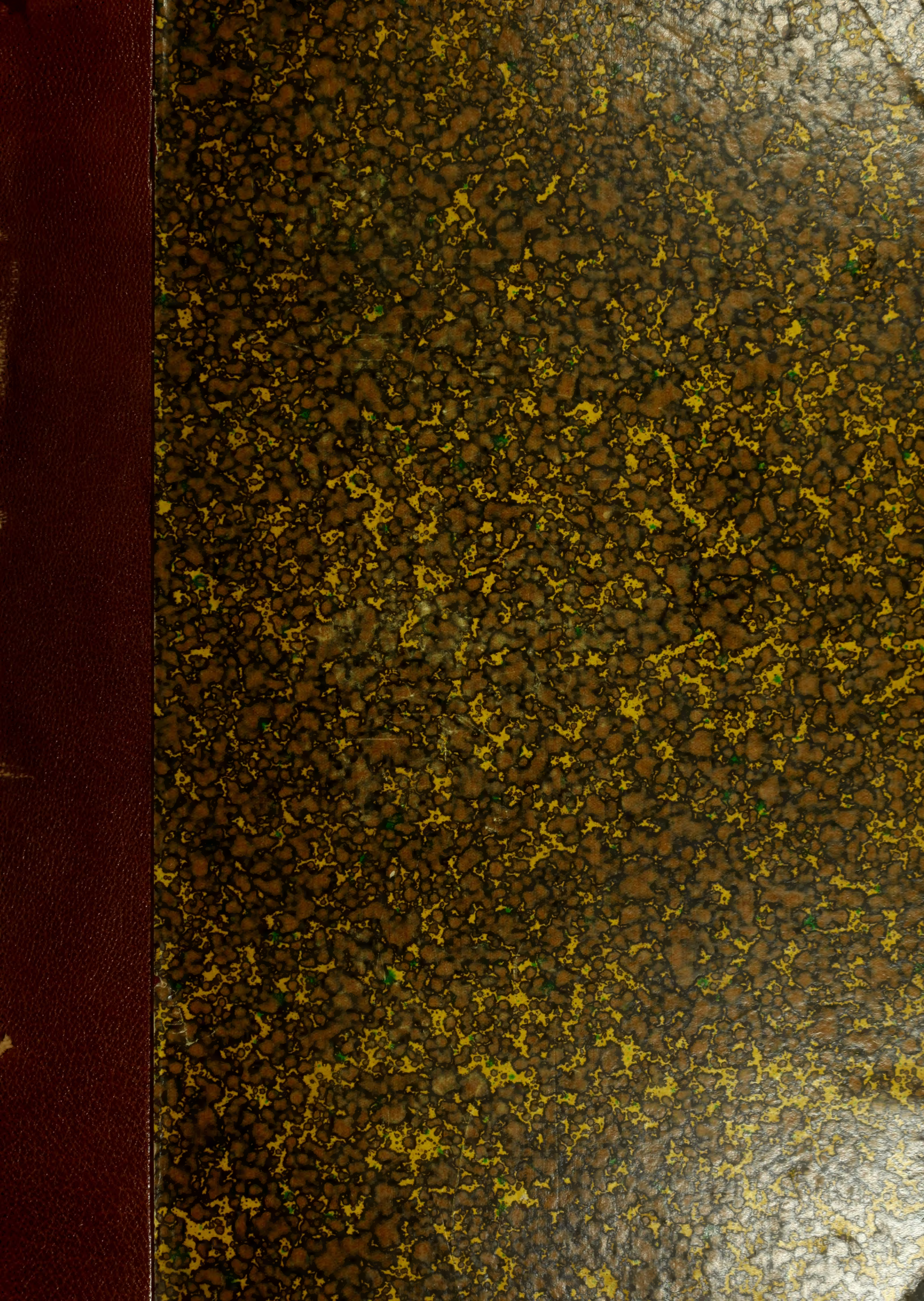
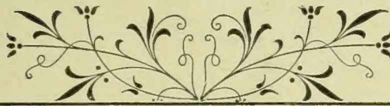


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Synthetic Rubber.

RUBBER enters so largely into engineering manufactures in one form or another, especially in matters electrical, and is moreover so high in price, that the announcement by Prof. W. H. Perkin, of the Manchester University, before the Society of Chemical Research in London, of a process for its artificial or synthetic production at a cost greatly inferior to that at which the natural product is now sold is of more than ordinary interest. The problem is one upon which chemists have been working for a long time, and as a scientific achievement synthetic rubber is not a new thing. Thirty years ago Sir W. A. Tilden in England and M. Bourchadet in France found that under certain conditions isoprene, a substance derived from some of the alcohols, was converted into real rubber, but as a commercial proposition it was impracticable on account of the difficulty of manufacture and expense. The important feature of the present discovery, which has been effected by a group of expert chemists, headed by Dr. Matthews, and organised by Messrs. Strange & Graham, Ltd., the well-known technical research chemists of London, lies in the fact that artificial rubber can, it is claimed, be manufactured on a commercial scale at a price which will put it into competition with the present plantation product. The essence of the discovery is that the raw material consists simply of starch derived from cereals such as maize or potatoes which can be produced in unlimited quantities, and cost on an average less than one penny per pound. According to Messrs. Strange & Graham only five operations are required for converting this starch into rubber, and these are easily performed, and give good results. The only other materials stated to be required are common salt and lime each costing about 30s. per ton, in addition to coal, say at 15s. per ton. It is asserted that the total cost of the raw materials for making one pound of rubber does not exceed twopence, and that with an abundant supply there is a large margin for manufacturing expenses if a shilling per pound be taken as the cost price, and that eventually the manufacturing cost

may be reduced to even sixpence or fourpence per pound. These figures will, if attained, not only make artificial rubber a practical possibility, but render it a very serious competitor to the plantation product. The present price of raw rubber ranges round 5s. per pound, and notwithstanding the large extent to which it is cultivated in plantations this price shows little signs of falling, owing to the extraordinary demand for the product, demands, it may be observed, which will increase in various directions if the price fell materially. It is in fact these latent and innumerable uses for rubber which will prevent any serious reduction in price for years to come, so that present investors in rubber concerns need not, we think, feel materially alarmed. So far the public have been given only a statement of what has been accomplished in the laboratory, and without impugning their accuracy it may be pointed out that between the laboratory and commercial production of a material is a big step often accompanied by many difficulties and disappointments. Experience often shows that an article synthetically produced by the chemist possesses different qualities to one built up by nature, although both are expressed by the same formula, and time only can decide whether artificial rubber will satisfy the requirements of practice so well as the natural product. So far, only a few pounds of artificial rubber have been made, and, in the absence of adequate durability tests, the announcement and claims respecting it seem a little premature. Some explanation of this was offered at a public demonstration of the process given last week by Messrs. Strange & Graham, Ltd., the organisers of the group of chemists who have conducted the research. The essential feature of the discovery—viz., that metallic sodium converted certain higher alcohols into rubber—was, it was stated, made some three months after Dr. Matthews by German chemists, and that while the Anglo-French group have been turning their attention to cheapening the process, the German firms have been making quantities of synthetic rubber from isoprene regardless of cost, for the purpose of a big show of manufactured goods at the Chemical Congress this autumn in America. In view of this the syndicate decided to make their announcement to secure priority for the fame of their discovery, for, apart from the action of sodium on isoprene, the cheap production, by fermentation, of fusel oil and acetone, the exclusive invention of the Anglo-French syndicate, is, they claim, even more important, and, as the company promotion announcement that has since appeared in the daily papers show, is to constitute the first commercial outcome of the affair. As a couple of years must, even according to the most sanguine estimate, elapse before synthetic rubber can enter the market in quantity, and as further time will even then be required to demonstrate its merits, present investors in the rubber industry need not, we think, be greatly concerned. The fact that the reported discoveries have been promptly followed by the request for money from the public will probably not be without its effect on shrewd business men. Discoverers of El Dorados certainly do not often invite outsiders to share their spoils.

The New Coal Mines Act.

THE new Coal Mines Act, which came into operation on Monday last, and which may be regarded as the outcome of the recommendations of the Royal Commission on Mines, contains a number of regulations which will materially add to the duties and anxieties of those responsible for colliery working. The provisions of the Act are mainly concentrated on the promotion of safety by stricter management, more thorough ventilation, better means of escape, and greater care in the use and testing of safety and rescue appliances. Except in the case of small mines, the approval of one of H.M. divisional inspectors will be necessary before a manager may undertake the supervision of more than one mine if the underground workers exceed 1,000, or if the mines are more than two miles apart, and when this year has expired no worker will be eligible for the position of fireman unless he is over 23 years of age and possesses a certificate from some approved mining school that he is competent to conduct tests for inflammable gases, speed of air currents, &c., and complies with satisfactory sight and hearing tests. To these provisions probably little exception will be taken, but some of the ventilation regulations will probably not secure unanimous approval. Henceforth a place will not be deemed in a fit state for working if the air contains less than 9 per cent. of oxygen or more than $1\frac{1}{4}$ per cent. of carbon dioxide (CO_2), while no intake air-way will be deemed normally free from inflammable gas if the average percentage exceeds $\frac{1}{4}$ per cent. The ventilation arrangements must also permit of the air current being reversed in new mines, while no fire will be allowed below for ventilation purposes. In new seams two main intake air-ways must be provided, only one of which is to be used for the haulage of coal, while the other must be kept free as an additional means of ingress or egress from workings. The value of this precaution has been demonstrated in several disastrous fires and explosions during recent years, and doubtless accounts for their enforcement, as also for the stricter regulation of the traffic and passage of workmen along haulage roads to be observed on and after January 1st, 1914. Only officials and those engaged in the haulage work or on repairs will then be permitted when haulage is in operation by gravity or mechanical power, unless the speed is under 10 miles per hour or the gradient is not more than 1 in 12, and a clear space of 2ft. is provided between the tubs and the side of the road, with whitewashed refuge holes at intervals. The new Act also imposes much stricter limits on the use of electricity, especially where there is risk of explosion from gas or coal dust, and if at any time the percentage of gas in a place where electrical machinery is employed exceeds $1\frac{1}{4}$ per cent. the current must be at once cut off. When the Act was being discussed in Parliament, it will be remembered, considerable opposition was raised by miners to the compulsory use of lavatory and bath accommodation at pit heads by men on leaving work, and in deference to the objections raised baths and clothes-drying facilities are only made compulsory where a two-thirds majority of the workmen intimate their desire for their provision. Under an order of the Rescue and Aids Act, the organisation and maintenance of rescue brigades, each of five persons, are now compulsory—one if the underground workers do not exceed 250, two if not less than 250 or more than 700, three if not less than 700 or over 1,000. There are numerous other rules and regulations, many of which will doubtless prove onerous and exceedingly difficult to enforce, and whatever may be their success in promoting safety, it is in the nature of things that they will tend to add to the cost of getting coal, and ultimately to the cost of iron, steel, and other engineering materials whose manufacture depends so largely on the use of coal as a raw material.

British Museum of Safety Appliances.

IT is satisfactory to learn that the proposed British Museum of Safety Appliances is taking practical form. The Home Office has secured a site at Westminster, plans have been prepared, and building, it is stated, will be begun as soon as

possible. The great educational value of museums of this kind has been discussed by us* and demonstrated in most continental countries. Institutions of the kind have existed for some time at Paris, Berlin, Vienna, Munich, Amsterdam, and Zurich, in addition to other important centres, and these examples have more recently been followed by America, where one has been installed at New York. Where employers, workmen, engineering students, and inspectors can obtain access to them, they have been much appreciated. It is not intended to limit the scope of the British institution to mechanical devices for the prevention of accidents, but to embrace industrial hygiene for the prevention of diseases of occupation, and to illustrate the correct principles of ventilation, lighting, &c., subjects which are of growing importance to the medical practitioners, as well as those engaged in particular occupations. Of the educative influence of such an institution we need not dilate, but to reap the greatest advantage industrial centres should be as closely in touch with it as possible. London is, of course, a natural centre from many points of view, but it is not convenient for dwellers in the great manufacturing towns, with whom it is especially desirable the exhibits should be brought in touch, and failing which such an institution would not attain its chief object, viz., that of securing the adoption of safety appliances and sanitary methods in workshops and factories. It is too much perhaps to expect that the large manufacturing towns will set up local museums of their own, though money is frequently spent on less deserving objects, and we think if interest were roused by practical demonstration of their value they would in many cases do so. For this reason, therefore, we trust, when a collection of appliances is assembled, efforts will be made either by the loan of exhibits or special travelling facilities to bring industrial centres in contact with them. Actual models and working demonstrations of safety appliances would do more to break down prejudices, and secure sympathy and co-operation in their use than any amount of official advice, which is often resented by employers and workers alike as an intrusion on their liberty. The idea of local museums bearing on special industries, to which all those engaged can secure easy access, is one we think greatly to be encouraged. Such a display as we have in mind would be more instructive and pertinent to their needs than the miscellaneous collections of curios, second-rate pictures, antedeluvian fossils, &c., which under the designation of museums are often put before them with a view to instruction, but which, in the majority of cases, we fear, excite only a languid interest.

British Motor-cars' Victories at the Grand Prix.

THE British cars in the international motor-car race for the Grand Prix of the Automobile Club of France, which came to a termination at the end of last week, scored a remarkable victory in the "restricted class," and also in the team race. The competitors were divided into two classes—the "open section" for cars of unlimited power, and the "restricted class" in which the maximum engine capacity allowed was three litres. The honours of the open section fell to a Frenchman with a Puegot car, after a long struggle with two big Italian cars, but he stood alone, and none of the other French cars had a look in with their German and Italian rivals. In the unlimited class no English makers entered, but in the restricted or "three-litre" class the English Sunbeam cars took first, second, and third place, and, further, secured the fifth and sixth positions in the combined race. Apart from the first place in the unlimited class, French cars did not show any prominence or enhance their national reputation, being beaten all round by cars from other countries. The result speaks well for the healthiness of the British car industry. Owing to legislative restrictions continental car builders in the early days had a big pull over makers here, and the result proves, given definite conditions of competition, British workmanship and design in motor engineering are capable of holding their own against anything continental competitors can put against them. The fact that no British cars entered the unrestricted class is due mainly, we believe, to the sound commercial instinct that the purchasers of pure racing cars are a limited few, and not worth special cultivation, or likely to provide so profitable a market as the small car of limited power.

* See "Mechanical Engineer," May 3rd, 1912, page 537.

Superheating in Portable Locomotives.

THE application of superheating to portable locomotives for agricultural purposes is somewhat of a novelty, but we see no reason why such an aid to economy should not be tried. The particular design embodied by Messrs. Ruston, Proctor, & Co., Ltd., and exhibited by them at the Royal Show, at Doncaster, on Tuesday last, and illustrated on page 4, is interesting. Unlike most railway locomotives, in which superheating has been mainly confined to single engines, the one in question is a compound, and the superheater consists of a series of steel coils placed in the smokebox, whereas in railway superheaters the trend of present practice is to place the superheater elements in large fire tubes to secure a higher temperature than is possible in the smokebox. But this, while contributing to economy, demands more skilled attention to prevent excessive superheating, and in Schmidt's system is accompanied with an automatic damper arrangement as a special precaution. It is probably a consideration of this possibility, coupled with the fact that agricultural engines have occasionally to put up with comparatively unskilled attention and that boiler pressures and rates of expansion are lower, that has led Messrs. Ruston, Proctor to adopt the smokebox design. The somewhat limited space available in engines of agricultural type will restrict to some extent the degree of superheat, though possibly sufficient will be secured to produce measurable economies in the steam consumption. At all events, the design is a novelty, and we shall watch its working with interest.

Dirigible Airship Disasters.

THE past week has been marked by two terrible disasters to airships. Another of Zeppelin's ill-fated craft met its end at Düsseldorf on Friday last, where, owing to rough weather, it failed to secure refuge in its shelter, and in its endeavours to weather the gale like a vessel in an open roadstead, was struck by a squall and broken in two, part being carried away by the wind, and the remainder set on fire and completely wrecked. About 30 persons were injured though no one was killed. The disaster, with the others that have preceded it, illustrates the unfitness of these huge craft to meet inevitable weather conditions, notwithstanding their high speed when circumstances are favourable. The one in question had, it is said, attained a speed of 45 miles per hour with her three 150 h.p. motors, but this only corresponds to a moderate gale that may spring up with hardly any warning, and when that is the case, the craft, unless it can succeed in making one of its special harbours, must lie more or less helpless at the

mercy of the wind. Aerial navigation for military or commercial purposes, and whether by heavier-than-air machines or by gas-inflated-bags, as things stand at present, is seriously limited by weather restrictions, though the advantage in any comparison between the two so far clearly rests with the aeroplane.

The second disaster, which was of a more terrible nature, occurred in America, where a dirigible balloon, designed with the reputed object of attempting to cross the Atlantic by Mr. Vaniman, was making a trial with a crew of four other men at Atlantic City, New Jersey, when it caught fire from some unexplained cause and exploded at a height of about 1,000ft., with the result that the balloon was destroyed and all the occupants killed. Mr. Vaniman, it may be remembered, was the engineer and companion of Mr. Wellman in the attempt to make a transatlantic voyage in the autumn of 1910, and which would have ended in disaster but for the fortunate presence of a ship when the airship broke down and they were compelled to alight in the sea. He also designed two airships for Mr. Wellman's polar expeditions, both of which were destroyed before their journey began.

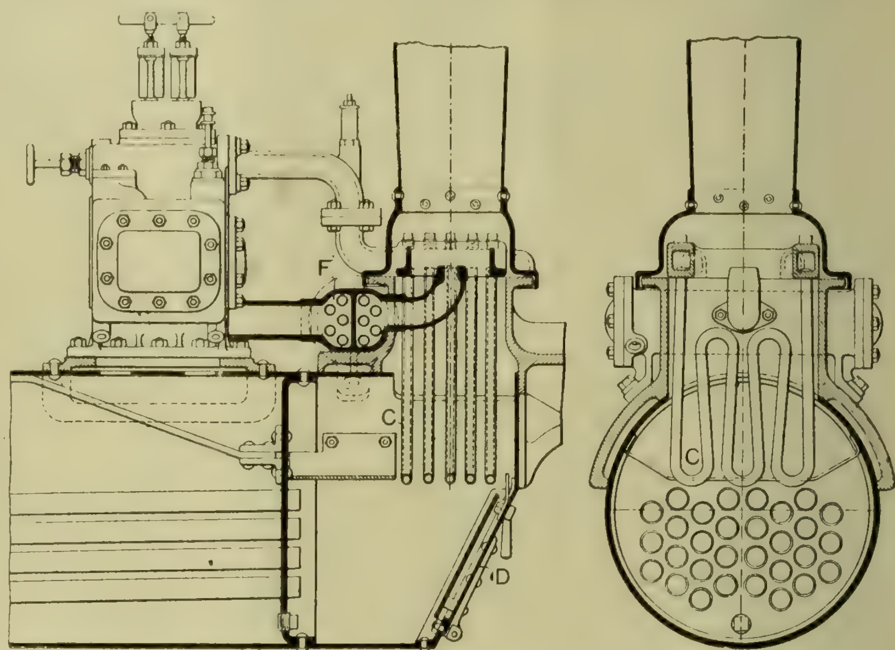
MEMORIAL TO "TITANIC" ENGINE-ROOM STAFF.

At a meeting held at Liverpool last week to promote a permanent memorial to the heroism of the engine-room staff of the "Titanic," Lord Derby said he did not think anyone could read the accounts of that great tragedy without realising the heroism of the engine-room staff of the "Titanic." They could but faintly picture what must have been the position of those brave men who, with certain death staring them in the face, were perfectly determined up to the very last to do what they could in the hope that their efforts might be the means, as they undoubtedly were, of saving the lives of others. These brave men had gone, and it was the duty of those who remained to perpetuate their memory, so that when the intimate knowledge of their great deed might have passed away, successive generations of Liverpool men might see recorded in some permanent place a record of their heroism. He hoped that the appeal would be made not only to Englishmen, but to people in every part of the world. Sir William Lever said that on the "Titanic" the highest traditions of British seamanship had been displayed. Referring to labour unrest, Lord Derby said that however despondent some pessimists might be as to the future of the country, and however much they might talk about its decadence, while such deeds as that which they wished to perpetuate took place, it showed that their people were composed of just the same material as those who made England great in the past. A nation which had lost its power to perpetuate the honour of brave men had lost its power to produce such men in future generations. Mr. A. J. Maginnis, who has been largely responsible for setting the movement on foot, announced that though no direct appeal had been made, £2,100 had already been subscribed towards the memorial. A letter was read from Lord Mersey wishing the movement every success.

The Iron and Steel Institute.—The autumn meeting of the Iron and Steel Institute will be held at Leeds on Monday, Tuesday, Wednesday, Thursday, and Friday, September 30th and October 1st to 4th next. An influential reception committee has been formed, with Lord Airedale as chairman, and including a number of influential men of the municipality, the Leeds University, and works in Leeds and the neighbouring districts.

STEAM ROAD ROLLER FITTED WITH SUPERHEATER AND FEED HEATER.

An interesting application of a superheater and feed-water heater to a steam road roller is exhibited by Messrs. Ruston, Proctor, & Co., Ltd., Lincoln, at their stand at the Royal Agricultural Society's Show, which opened on Tuesday at Doncaster. The engine is of the side-by-side compound type, with cranks at right angles, and is provided with an auxiliary valve, by means of which high-pressure steam can be admitted to the low-pressure cylinder when desired. This arrangement is found advantageous in starting, and also when ascending steep inclines. Both the high and low pressure valves are of the slide type, and are easily accessible. The arrangement of superheater and feed-water heater is clearly shown in the accompanying sectional views. The superheater is arranged in the smokebox above the boiler tubes, and consists of a series of steel coils C, terminating in steel headers. It is readily accessible through the door D, and is so placed as not to interfere with the cleaning of the smoke tubes. The steam can when necessary be by-passed round the superheater and led direct into the cylinders. The feed-water heater shown at F comprises a series of tubes arranged in a casing fitted in the exhaust steam pipe. It also serves to silence the exhaust. Tests made by the makers with the new arrangement show a considerable economy over the ordinary type of compound roller.



STEAM ROAD ROLLER FITTED WITH SUPERHEATER AND FEED HEATER.

Comparative Merits of Different Systems of Traction.—At the recent annual congress of the Tramways and Light Railways Association, an exhaustive paper on "The Respective Values of Tramways, Motor-buses, and Railless Traction as a Means of Transport" was read by Mr. A. H. Pott, chief engineer of the Metropolitan Electric Tramways, Ltd. Tramways are, he said, the best means of conveying cheaply numbers of people, but fresh legislation is required to place tramways in a not less favourable position than other means of locomotion which may be in competition. Omnibuses are most suited to towns where roads are narrow or not straight, and where for these reasons vehicular congestion is great. Railless traction can best provide travelling facilities beyond a tramway terminus, provided that the surface is good and traffic is sufficient to justify, say, a 15 minutes' service. It is desirable that there should be fresh legislation in regard to the promotion and operation of all methods of street locomotion, and that Parliament should leave all minor details in regard to working in the hands of one department. There is a want of closer working arrangements between all transport undertakings.

DE LAVAL MULTI-CELLULAR TYPE STEAM TURBINE.

A design of steam turbine of the multi-cellular type has recently been introduced by the De Laval Steam Turbine Company, of Trenton, N.J., U.S.A. A sectional view of the turbine is shown in Fig. 1. The rotating member consists of a heavy shaft upon which is mounted a series of discs or wheels, each revolving in its independent cell or chamber formed between diaphragms. The steam flows from the steam chest at the right-hand end of the casing, through nozzles, and impinges upon the buckets of the first wheel. The nozzles employed in the first stage are formed of tubes carefully bored and reamed and set in the nozzle ring, or they may be bored and reamed directly in the nozzle ring itself. The nozzles of this stage occupy only a portion of the circumference, thereby avoiding the difficulties of short blade lengths encountered where full admission is employed in the first stage. Any or all of these nozzles may be controlled by hand-operated valves seating upon the inlet openings. These valves, however, are not used for speed regulation, and are not operated automatically, as it has been found that the opening or closing of one or more nozzles at a time by a governor is apt to induce surgings and fluctuations in speed, and the automatic control of separate nozzles requires a complicated governing mechanism.

The buckets against which the steam impinges are made of a special alloy containing nickel and copper, and are drop forged. The tips of the buckets have lugs which fit against similar projections on the adjacent buckets, forming a continuous rim, which is advantageous in diminishing the fan action of the buckets and also in that it prevents spilling, by confining the jets of steam within closed channels. The rim also maintains the proper spacing of the buckets and greatly strengthens them by preventing vibration. The buckets are secured to the rim of the wheel by transverse dovetails, which permit of the removal or insertion of individual buckets without disturbing others, and further forms a strong attachment without greatly increasing the load on the wheel by the weight of additional metal.

The cross-sectional area of the passages is increased for the expansion of the steam by lengthening the buckets, reducing the diameters of the wheels correspondingly and increasing the bore of the casing. The length and strength of the buckets used in the last wheel determine the maximum speed at which the turbine may be operated, while the length of these buckets and the diameter of the wheel determine the maximum capacity for given steam conditions. A proper balance of these factors, and proportioning of the last wheel with respect to diameter, pressure drop, capacity and terminal pressure, is rendered possible by the use of the De Laval speed reduction gear through the freedom afforded the designer in the choice of rotative speeds. In gaining the desired bucket velocity by increased speed or rotation, rather than by larger wheels, skin friction, leakage, and other losses throughout the turbine are reduced.

The wheels upon which the buckets are mounted are forged steel discs, finished and ground on all surfaces and proportioned to safely withstand rotating speeds much higher than the normal operating speed of the turbine. The hubs of adjacent wheels touch one another, permitting them to be locked in place by one nut, and at the same time adding considerably to the stiffness of the shaft. The shaft is so designed that its critical speed, even without the reinforcement received from the wheel hubs, is far above the operating speed. The wheels are mounted upon the shaft by means of taper bushings, which ensure perfect centring and permit of easy removal of the wheels when necessary. With the exception of the nozzles in the initial stage, the nozzles of each succeeding stage are formed between guide vanes set around the entire periphery of the diaphragm. These vanes are of nickel-bronze. They are spaced and located upon the rim of the diaphragm by pins and are held in place by a steel band shrunk over their tips. Two pins are used for each vane to determine its proper angle, and therefore, in connection with the shape of the vanes, to fix the contour and the cross-sectional area of the nozzles formed between the successive vanes. The steel bands are wider than the blades and diaphragms. Adjacent bands touch one another, forming a continuous cylinder, which encloses not only the diaphragms, but also the rotating wheels, providing a complete lining of forged steel for the wheel case. The cast-iron diaphragm discs are perforated at the centre and are fitted with removable labyrinth packings in order to minimise the leakage of the steam from stage to stage between the diaphragms and the cylindrical wheel hubs.

The rings surrounding the guide vanes and diaphragms rest in a cast-iron wheel case, split horizontally to render all working parts of the turbine accessible. On account of the comparatively limited number of stages in the turbine the length of the wheel case is moderate, and furthermore, as it contains no cored passage or unsymmetrical parts, it is free from distortion due to changes in temperature. To enable the case to expand freely in all directions without altering the position of the axis and throwing the centre lines of the wheel case and shaft out of the same plane, the wheel case is supported in the plane of its centre line upon two pedestals rising from the bedplate. These pedestals permit the diametrical expansion of the case, while the holding-down bolts, except one on each side, have oval bushings and are prevented from clamping by shoulders on the bolts where they are screwed into the pedestal and the case is free to expand longitudinally between guides on these pedestals. It is claimed that this arrangement not only prevents distortion, but enables the expansion of the case to increase the axial clearances.

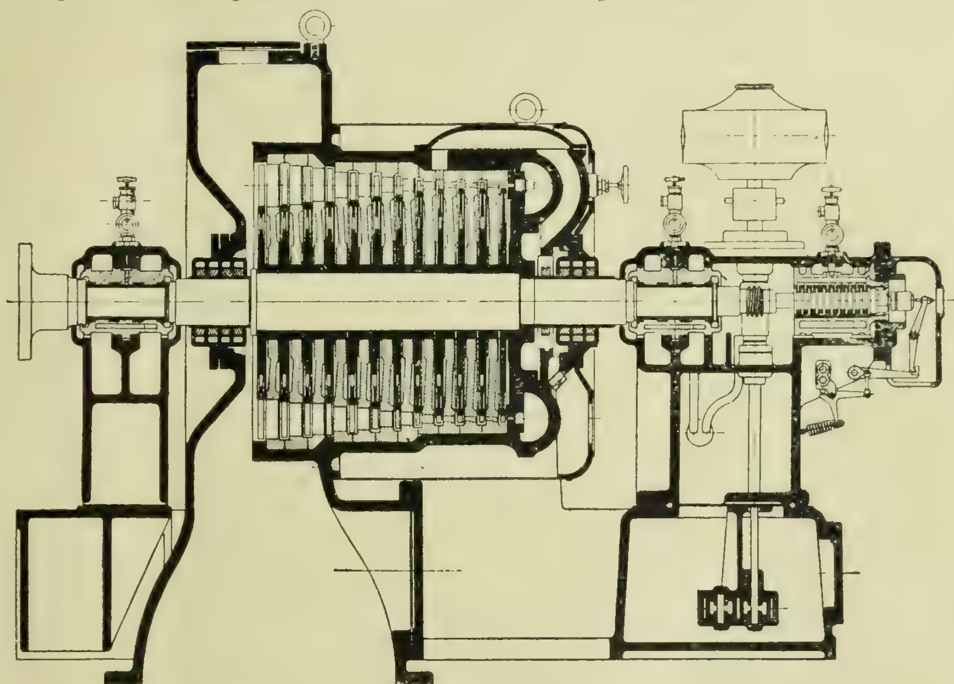


Fig. 1.—Axial Section, Showing General Arrangement of the De Laval Multistage Steam Turbine.

The use in a multi-stage turbine of a shaft running above or near its critical speed is an error, because any eccentric rotation of the shaft will require enlarged clearances where the shaft passes through the diaphragms; in other words, the leakage areas will need to be considerably increased. The total leakage, therefore, is reduced by using a shaft sufficiently large and stiff to suppress such vibrations entirely, as the radical clearance may be correspondingly reduced. This course has been adopted in the turbine under notice, the shaft of which is so large that the critical speed is far higher than the normal running speed of the turbine, even neglecting the stiffening action of the wheel hubs. The small number of stages requiring only a moderate over-all length, makes it possible to place the shaft bearings close together, which increases the critical speed of the shaft, and reduces the tendency to vibration. As the pressure of the steam is equal on both sides of any wheel or bucket, the only leakage possible is from stage to stage along the shaft at the point where it passes through the diaphragm and the turbine casing. The problem of minimising such leakage is, however, greatly

simplified by the fact that the pressure difference existing between any two adjacent stage cells does not exceed a few pounds. The labyrinth packing employed at these points is unusually long and the stiffness of the shaft permits of a minimum running clearance. In the first stage leakage outward to the atmosphere is first obstructed by a labyrinth packing of double length, and any steam leaking past it is led back to an intermediate stage and utilised at a lower pressure for generating power. Following this packing is a

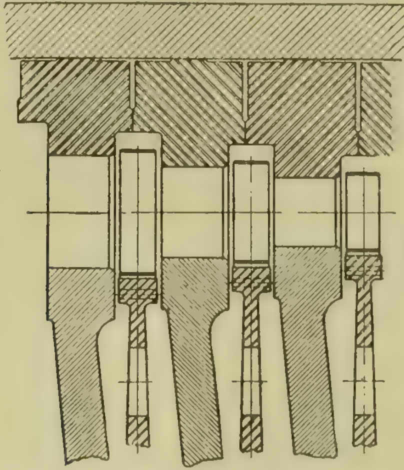


FIG. 2.—PARTIAL SECTION OF TURBINE SHOWING THE FORGED-STEEL RETAINING RINGS WHICH FORM A CONTINUOUS ARMOUR ENCLOSING THE WHEELS.

series of segmental carbon ring packings, each of which is enclosed in a separate compartment. The leakage past the first carbon ring is carried back to the exhaust connection of an intermediate stage of the low-pressure packing and live steam is introduced between the two outer rings, so that any inward leakage along the shaft will be steam and not air. Similar carbon rings are employed in the exhaust end and steam is introduced for the same purpose.

There are three bearings in the multi-stage turbine, two of which support the weight of the revolving parts, and the third being a thrust bearing. All parts of the turbine requiring lubrication are supplied with oil by a circulating pump of the positive gear type, driven from the lower end of the governor spindle. The supply of oil for this pump is drawn through screens from a large reservoir in the bedplate of the turbine, and is forced to an elevated storage tank and flows thence by gravity to sight-feed lubricators on each bearing. The bedplate of the turbine is of the box type, and

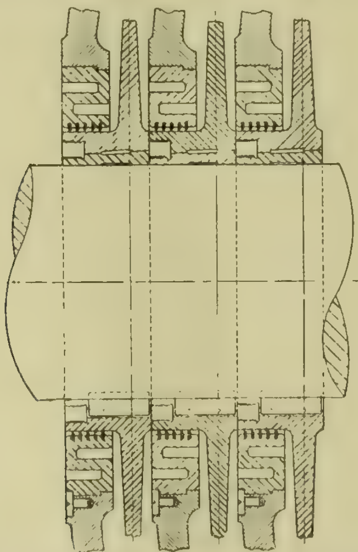


FIG. 3.—SECTION SHOWING METHOD OF ATTACHING WHEELS TO SHAFT BY TAPERED SLEEVE DRAWN INTO PLACE BY A NUT AND HELD FROM ROTATING ON SHAFT BY A KEY. ALSO THE LABYRINTH PACKING BETWEEN DIAPHRAGMS AND HUBS OF WHEELS.

contains the main oil reservoir, oil strainer, and oil pump. The low-pressure end of the turbine bedplate is faced for connection to the bedplate of the driven machine.

The governing of the De Laval turbine is accomplished by throttling the admission of steam to the steam chest. The governor is of the Jahns type and is mounted upon a vertical shaft driven from the turbine shaft by worm gearing. The governor-valve is of the double-seated, balanced, poppet type, having adjustable valve discs and removable seats. The valve discs are of a peculiar umbrella shape, designed to avoid unbalancing at different positions or rates of flow. The materials used for the valve body, discs, and seats depend upon the pressure and temperature of the steam. For ordinary pressures the valve body is made of cast iron and the discs and seats of non-corrosive metal, but for superheated steam steel is used throughout.

To provide against any possibility of racing, through derangement of the speed governor, or because of an accident to the transmission from the turbine shaft to the governor or from the governor to the valve, a safety stop and a quick-operating trip and throttle valve are provided. The safety governor is mounted in the end of the main turbine shaft, entirely independent of the main speed governor, and may be adjusted to act at any predetermined speed. The governor trips a small valve which releases steam pressure from under a small piston in a combined trip and throttle valve, when the balanced disc of the latter will immediately be forced shut by the pressure of the steam acting upon a piston. This trip valve is placed ahead of the main governor valve and protects the turbine in case of leakage in the latter. It can also be tripped by hand and is intended for use as a throttle valve for starting and stopping the turbine.

WHY MANGANESE-BRONZE CASTINGS LEAK UNDER PRESSURE.

THE extensive use of manganese-bronze at the present time and the fact that it is a strong metal has been responsible for the troubles of many brassfounders. An order is received for castings to be used for hydraulic work, high air pressure, or similar goods. The brassfounder immediately thinks of manganese-bronze as the suitable mixture from the fact that it is the strongest one that he makes. The very fact that the metal must stand a high pressure renders it necessary, in his own mind, that a strong bronze must be employed. The order may, however, specify manganese-bronze, and if this is the case, then, of course, he gives the matter no thought, but starts in to use it. In either instance, accordingly, the effect is the same and the casting is made out of manganese-bronze.

The castings made, they are shipped to the customer, who machines them and then proceeds to test them. A large percentage, and not infrequently all of them, leak. The castings may look perfectly sound, not a blowhole or flaw in them, but yet they leak. The unfortunate brassfounder then imagines his heat of pouring or his mixture is wrong, and, although the profit is already gone from the job, he makes the castings again, but with the same result. Perhaps a smaller percentage of them leak this time and then he believes that his pouring heat was at fault and he may make another trial. He usually finds, however, that he cannot obtain a sufficient number of good castings which do not leak to warrant filling the order, and he then usually "throws up the job."

The reason that manganese-bronze castings leak in this manner is on account of the aluminium in them. They cannot be made, however, without the aluminium, which oxidises when melted and wherever exposed to the air. There is always a film of oxide on the metal when it is poured, and this film becomes intermingled with the molten stream and enters the casting. So far, there has been no known method of keeping it out. Watch a stream of molten manganese-bronze and see it go in! The oxide of aluminium, however, is white and while it can be noticed going in with the stream of molten bronze, in the casting, on account of its white colour, it is not visible. The result is that the casting is filled with particles of oxide of aluminium, but which are not visible. When pressure is applied in testing the casting, these particles (they are frequently flakes as the microscope will show) form channels, on account of not uniting with the metal, through which water, air, or other liquids or gases may pass. Hence the leakage. The remedy is to make castings to stand pressure of a good copper and tin mixture that will cast without a film of oxide and give a clean metal. This has been the universal verdict so far.—"The Brass World."

THE CORROSION OF IRON AND THE PROTECTION OF STRUCTURAL IRONWORK.*

BY L. ARCHBUTT, F.I.C.

THE subject on which you have invited me to address you is one of very great importance and no little anxiety to engineers. It is a subject of considerable complexity, and one to which adequate justice cannot be done in the short space of one lecture. I shall, therefore, have to ask your indulgence if I have to treat it in a somewhat sketchy manner, but I will endeavour to put before you some of the main facts which our present knowledge shows to be of importance. It is a subject on which a vast amount of literature exists, and on which a great deal of work has been done, but it is within only quite recent years that the work done has been systematic, and very much still remains to be done.

Iron, and its alloys with carbon and some other elements which we call steel, is the most useful of all metals on account of its great strength, abundance, and general adaptability for constructional work, but unfortunately it is also one of the most perishable of metals, under the atmospheric conditions which are normal in this and many other countries, and under water. It is easily attacked by nearly all acids, by alkalies under certain conditions, and by oxygen in presence of water, and yet if it can only be kept dry and in a clean atmosphere it will remain unchanged for centuries. Dry air, at the ordinary temperature, has remarkably little effect upon iron. Zumstein,† in August, 1820, fixed a polished iron cross on the summit of Monte Rosa, and on visiting the spot 12 months later found the iron quite free from rust and with only a slight, bronze-coloured tarnish upon the surface. At temperatures much above the normal, oxygen of course readily attacks iron, but for rusting to occur at the ordinary temperature, and at temperatures below and not much above the normal, the presence of water is essential.

In damp situations, as we all know to our cost, iron and steel oxidise rapidly, becoming converted into the familiar red rust, and this process is hastened by the presence in the air of carbonic acid, nitric acid, sulphurous and sulphuric acids from the combustion of coal and imperfectly purified coal gas, such as the gas companies are allowed to sell us, chlorine and hydrochloric acid from chemical works, &c. These acid gases are not nearly so injurious in the absence of water as in its presence, and generally it may be stated that the cleaner and dryer the air the longer will iron last in it. A remarkable instance of the preservation of unprotected iron in a by no means dry atmosphere is the celebrated iron pillar in the Mosque of Kutab, near Delhi, built up of iron blooms forged nearly 3,000 years ago, yet said to be so free from rust as to be merely tarnished upon the surface.

Pure water, free from oxygen and carbon dioxide, has so little action upon iron that if a clean strip of the metal be dropped into boiling distilled water in a clean glass flask, well boiled with the water, and the flask sealed up while the water is boiling, the bright surface will remain untarnished for an indefinite period, though a few spots of rust may form here and there owing to the local impurities in the metal. There seems to be no doubt that the iron dissolves to a very slight extent in the water, but whether it would dissolve in chemically pure water is still a doubtful point, owing to the extreme difficulty in obtaining water absolutely pure and free from every trace of carbon dioxide. Water vapour, oxygen, and carbon dioxide, either singly or together, have no action upon iron or steel at ordinary temperatures, provided the water vapour is prevented from condensing upon the iron. Museum specimens of iron or steel, such as broken test-pieces, with their bright fractured surfaces, can therefore be preserved indefinitely free from rust if the precaution be taken to maintain their temperature well above the dew point of the air of the room or case containing them.

It was formerly accepted without question among chemists that the rusting of iron commenced with an attack by carbonic acid or some other acid‡ Water containing in solution carbonic acid first attacks the iron thus, $Fe + H_2CO_3 = FeCO_3 + H_2$, forming ferrous carbonate, which dissolves in the water, and hydrogen, which escapes (or becomes oxidised by the oxygen in the water).

The ferrous carbonate is immediately oxidised by the oxygen dissolved in the water, with formation of the red ferric hydroxide and liberation of the carbonic acid, which again attacks more iron, $4FeCO_3 + 6H_2O + O_2 = 2Fe_2(OH)_6 + 4CO_2$. This process continues until the whole of the metal is converted into a mass of red rust. The rust which adheres to the iron forms a kind of porous plaster, which, by holding the water and carbonic acid in contact with the metal, accelerates the rusting. In this connection it may be noted that the rust produced under ordinary atmospheric conditions usually contains some carbonic acid. There is no doubt that this is the process which takes a very active part in the aerial rusting of iron, but within the last nine or ten years other theories have been proposed to account for the rusting.

About 1903, Whitney,* an American investigator, proposed an electrolytic theory, denying that the presence of an acid was essential, and maintaining that iron could rust in the presence of oxygen and water alone. Whitney and his followers, Walker, Cushmann, and others, maintain that the process is purely electrolytic, the water condensed on the surface of the iron, or in which the iron is immersed, being supposed to be dissociated to a small extent into free hydrogen and hydroxyl ions carrying opposite electrical charges. A minute quantity of the metal iron is supposed to dissolve in the water, forming free ferrous ions, a proportionate number of hydrogen ions becoming deposited upon the surface of the metal and losing their electric charges. In the meantime the ferrous hydroxide formed by the union of the ferrous ions in the water and the hydroxyl ions becomes oxidised by the oxygen, and separates out of solution as red ferric hydroxide or rust. More metallic iron then goes into solution and the process continues. The truth of this theory depends upon the proof (1) that chemically pure water is capable of conducting a current, and (2) that pure iron can dissolve in chemically pure water. As the difficulties in the preparation of chemically pure water free from the least trace of carbon dioxide have hitherto proved insurmountable, the truth of the electrolytic theory still remains to be proved, and it is hotly disputed by the advocates of the rival theories. A very clear and able account of the electrolytic theory of corrosion is contained in a paper by Dr. W. H. Walker read before the Iron and Steel Institute in 1909 (Vol. 1, p. 69). It cannot be denied that electrolytic action plays a very important part in corrosion, but that is quite another thing from admitting the rationale of corrosion as explained by the electrolytic theory.

A third theory was suggested by Dunstan,† Jowett, and Goulding a few years ago. Dunstan also believes that iron can rust in presence of oxygen and water alone, without the intervention of any acid. He found that certain substances which, when dissolved in water, prevent the formation of rust, also destroy or prevent the formation of hydrogen peroxide, and that on the other hand rusting readily occurs in the presence of other substances which have no action upon hydrogen peroxide. He therefore concluded that hydrogen peroxide played an important part in the rusting of iron, although, curiously enough, he was never able to detect a trace of it in the water in which iron was rusting, though readily detected in the water in which certain other metals, such as zinc and aluminium, were undergoing oxidation. Dunstan and Hill‡ in a more recent paper claim to have detected traces of hydrogen peroxide in the case of iron. Fatal objections to this theory are, however, the facts that chemically pure hydrogen peroxide is entirely without action upon iron,‖ and that iron has been shown to rust easily in the presence of potassium oxide and certain other substances which decompose hydrogen peroxide.

The most conclusive experiment proving that iron free from more than traces of impurity will not rust when kept wetted with water containing oxygen, but quite free from carbonic acid, is due to the ingenuity of Friend¶. A hollow

*Paper read before the Derby Society of Engineers.
†Brit. Assoc. Reports, 1838. p. 255
‡Grace Calvert, Manchester Lit. & Phil. Soc. Trans., 1871.
Crum Brown, J. Iron & Steel Inst., 1888 (2), 129.

*J. Amer. Chem. Soc., Vol. 25 (1903), p. 394.
†Trans. Chem. Soc., Vol. 87 (1905), 1548.
‡Trans. Chem. Soc., Vol. 99 (1911), 1835.
‖Moody, Trans. Chem. Soc., Vol. 89 (1906), 729.
¶Iron and Steel Institute. Carnegie Research Memoirs. 1911 (3) 1.

cylindrical bulb of iron or mild steel, closed at one end, is fitted with a rubber stopper carrying two glass tubes, by means of which a current of cold water can be circulated through the bulb. The outer surface of the bulb having been brightly polished with emery cloth, it is fixed in the upper part of a glass flask containing some fairly strong caustic potash solution. The air in the flask is reduced somewhat in pressure, and the flask is then hermetically sealed. By thoroughly shaking the caustic potash solution in the flask, every trace of carbonic acid is removed from the walls of the flask, the surface of the steel, and the enclosed air. The potash solution is then heated nearly to boiling, whilst a current of cold water is caused to circulate through the bulb, causing water quite free from any trace of acid to condense upon the surface and gradually wash off the potash solution. Under the conditions of this experiment the iron or steel, though wetted with water containing dissolved oxygen, remains bright and unrusted for an indefinite period, though an isolated spot of rust may form here and there owing to some local impurity in the metal. It has been objected* that in this experiment the surface of the iron is rendered "passive" by the potash which is washed over it, and thereby protected from rusting, but Friend† has shown that the so-called passive state of iron produced by the action of alkalis is not a true passive state, such as is produced by the action of strong nitric acid and some other acids, and which is believed to be due to the formation of a superficial protective film of oxide. The apparently passive state produced by alkalis is an effect due to the absorption of the alkali by minute pores in the surface of the metal, and held there with considerable tenacity. If this alkali be thoroughly washed out with distilled water the passivity disappears, and Friend claims that it is thoroughly washed out under the conditions of his experiment.

However interesting it may be from an academic standpoint to settle the very vexed question whether the presence of an acid is or is not essential to the rusting of iron, and its interest is proved by the fact that for the last ten years it has been the subject of experiment by a host of investigators in this country, Germany, and America, the practical importance of the point is largely discounted by the fact that under natural conditions the acid is always there. All water condensed from the atmosphere, whether in the form of rain or dew, besides being saturated with oxygen, contains in solution carbonic acid, and to this must be added, in the neighbourhood of towns where coal is burnt and where chemical works exist, stronger acids such as sulphuric, hydrochloric, and nitric acids. These acids commence the attack upon the iron, but it is the oxygen which converts the product into rust, and removing the dissolved iron from solution and liberating the acid for a fresh attack is the most potent agent in promoting corrosion. In a recent paper by Longmuir‡ it is shown that rain falling in a manufacturing district may contain as much as 7·3 grains of sulphuric anhydride and 8·1 grains of chlorine existing as chloride in one gallon, and that the sulphur in chimney soot may range from 1·44 to 3·60 per cent., or if expressed as sulphuric anhydride from 3·60 to 8·59 per cent. Much of this exists as sulphuric acid. Iron rust formed in towns always contains sulphuric acid. Longmuir mentions a case where steel ingots containing as little as 0·02 per cent. of sulphur gave rust containing 1·25 per cent. when allowed to rust in the open air.

Sulphuric acid formed by the combustion of coal in locomotives is the active cause of the serious corrosion of rails which sometimes takes place in tunnels. In the rust removed from such rails in active service I have found twelve times as much sulphur as could have been derived from the steel rail itself. I once calculated that in the case of a particular tunnel the steam from the locomotives on condensing to water would form drops containing at least 0·41 per cent. of sulphuric acid, which would be highly corrosive to steel, and in the surface dirt scraped from newly laid rails in this tunnel I found 3·33 per cent. of sulphuric acid soluble in water. A short length of rail, 4ft. long, was placed in this tunnel in

* Dunstan & Hill, loc. cit.
† Trans. Chem. Soc., Vol 101. (1912) 50.
‡ Jour. Iron and Steel Inst. 1911. (1) 147.

the 6ft. space, clear of the ballast, on two wooden pegs, in February, 1898. After remaining for 3¼ years exposed to the air and smokebox gases it was removed for examination and analysis.

The piece of rail was corroded all over with rust and dirt, varying in thickness from about $\frac{1}{12}$in. to ¼in., and composed of two layers, an inner, dense layer, about $\frac{1}{16}$in. thick, of red and yellow oxide, and an outer, soft, black layer, thicker on one side of the rail than the other, partly consisting of soot, but mixed with bright yellow basic sulphate of iron, containing 10·85 per cent. of combined sulphuric acid. Some of the rust was detached from the rail and submitted to analysis. Some drillings were also analysed, taken from the rail itself. The following results were obtained:—

Analysis of Rail.		*Analysis of Rust.*	
Carbon	·275	Ferric oxide	78·73
Silicon	·070	Ferrous oxide	2·12
Sulphur	·048	Sulphuric anhydride.	4·22
Phosphorus	·044	Water, &c.	14·93
Manganese	1·114		
Iron	98·56		100·00
	100·111		

		Ratio.
Sulphur in rail, per 100 parts	·048	1
,, ,, rust, ,, ,, ,, of rail	2·92	61

Thus the rust contained 61 times as much sulphur (existing as combined sulphuric acid) as was contained in the rail from which it was formed.

The rust attached to iron in active corrosion will sometimes be found to be composed of layers which are red and yellow on the outside, and more or less dark green or black inside in contact with the iron. The outer layers where the oxidation has proceeded farthest are ferric hydroxide, the inner layers ferrous hydroxide. The presence of the two oxides is interesting, because it shows that iron in contact with the moist red oxide under conditions where is cannot readily obtain oxygen from the air or from water will take it from the more highly oxygenated red oxide with formation of the lower green oxide. This kind of action takes place at great depths under water where the supply of oxygen is limited. When iron becomes converted into red rust it has been estimated that the volume increases ten times. This enormous expansion has a very important bearing upon the instability of ferro-concrete when the embedded iron or steel is not absolutely protected from the possibility of corrosion.

To the other causes which lead to the corrosion and destruction of ironwork must be added the action of bacteria. There are many kinds of bacteria in whose life-history the element sulphur plays an essential part. Some reduce oxidised sulphur compounds to sulphuretted hydrogen, others oxidise the sulphuretted hydrogen and store up the sulphur, others again further oxidise the sulphur to sulphuric acid and produce an acid condition in the soil. In an interesting paper by R. H. Gaines* mention is made of serious damage to the foundation structure of a bridge crossing Lake Hauser in Montana, which is said to have been traced to the action of a bacterium, *Gallionela ferruginea*, which eliminates an acid secretion by which iron is dissolved and then assimilates the iron, which ultimately becomes converted into ferric oxide in its cell walls. Many bacteria which feed upon iron in a similar way are known, and some of these cause great trouble in water pipes, forming masses of the red oxide which eventually choke the pipes. The remedies for the external corrosion of ironwork caused in this way recommended by Gaines are free drainage, by which the acid secretion is carried away, and where this is impracticable, mixing slaked lime with the soil to neutralise the acid which is formed. Cushmann found that the addition of 5 per cent. of lime to boggy, sour land, exerted a very marked protective influence on iron embedded in it.

As rusting is essentially a process of oxidation and is dependent upon the oxygen dissolved in water, considera-

* Jour. Ind. and Eng. Chem. 11, No. 4.

tions such as the superficial area of the water, the rate of flow of rivers, and the depth of immersion of the iron have an important bearing in connection with immersed structure, such as the piers of bridges. As water obtains its oxygen from the atmosphere it is well to remember that oxygen is much more soluble in water than nitrogen, and that the ratio of oxygen to nitrogen in the gases dissolved in water is 1·2, whilst in air it is only 1·4. In still water, as in tanks, the rusting of iron can be checked by interposing between the surface of the water and the air some insulating material. Charcoal, for instance, has a great power of absorbing gases, and in experiments made by Heyn and Bauer* it was found that the relative rate of corrosion of wrought iron in distilled water was reduced from 100 to 68 by suspending a block of charcoal in the water, and from 100 to 20 by covering the surface of the water with a layer of powdered charcoal. The depth of immersion influences the rate of corrosion in two ways (1) by its effect on the dissolved oxygen and (2) by the difference in the intensity of light. Gases diffuse through water slowly, consequently the oxygen which the iron removes from the water in rusting is more rapidly renewed near the surface, and as rusting is promoted by light it goes on more rapidly the less deeply the iron is immersed. At the surface, where the oxygen and light are in greatest abundance, and where also the temperature is highest, the corrosion is greatest, and the iron if unprotected may even be cut through at this point.

Sea water, as is well known, is much more corrosive to iron than fresh water. Adie in 1845 found by experiment that wrought iron wire immersed for 80 days in sea water lost in weight 37 per cent. more than when immersed in fresh water under similar conditions. Yet oxygen is less soluble in sea water than in fresh water. The greater corrosive action is due to the presence in sea water of magnesium chloride, a very corrosive salt. Iron is, in fact, corroded by sea water, even in absence of oxygen. Old iron guns and cannon balls which have been dredged up from the bottom of the sea after many years submergence have frequently been found to have become more or less completely converted into soft masses of ferrous oxide, mixed with the graphite and silica from the cast iron they were made of.

For the preservation of iron or steel structures subject to atmospheric rusting several methods are available. Many years ago Barff, noticing the protection to rolled iron afforded by the mill-scale, proposed to form such a coating of scale upon the surface of iron or mild steel articles by heating them to from 400° Fah. to 600° Fah. in a current of superheated steam. At this temperature iron decomposes steam thus:— $3Fe + 4H_2O = Fe_3O_4 + 4H_2$, and a protective film of the black magnetic oxide Fe_3O_4 is formed upon the surface of the iron. The weak point of the process, apart from its cost, is the readiness with which the oxide cracks and flakes off when the metal is hammered or bent, thus exposing the iron, and as iron is electropositive to the oxide, active corrosion and pitting of the exposed metal is promoted.

The processes of tinning and galvanising are much more extensively employed. In the first process, the iron is pickled in acid to remove rust and scale, washed to remove the acid, and passed through a layer of melted fat into a bath of molten tin which adheres to the surface of the iron and forms a protective coating, if well done, and so long as it remains intact. But if there are any pin holes or defective places in the tin coating, where the iron is exposed, the tin is the reverse of protective, as being like the black oxide, electronegative to iron, rusting is promoted. A much more effective process is that of galvanising, in which a coating of zinc is formed upon the iron. There are at least three methods of galvanising. The first and oldest is similar to that employed in making tinplate. This process, when well done, forms an alloy of iron and zinc upon the surface of the metal, which is not only a good protection so long as it lasts, but which does not fail if there should be small holes in the coating, zinc being electropositive to iron. The iron is, therefore, protected so long as the coating lasts, and as zinc withstands ordinary atmospheric influences very well, the coating of oxide at first formed protecting the metal from further attack, well galvanised iron and steel will often last a very considerable time. Cruikshank considers, however, that such structures should be painted over the zinc, and to prevent the paint from peeling off he recommends treating the galvanised surface with a solution containing copper before the paint is put on.

More modern processes of galvanising are the electrolytic, in which zinc is deposited upon the iron by electrolysis, and the interesting process known as Sherardising, in which the articles to be coated are rotated with zinc dust in a hollow drum heated to a temperature below the melting-point of zinc. Under these conditions, the vapour of zinc combines with and forms a coating of the metal upon the iron surfaces.

The weak point of galvanising is that zinc is a very easily corroded metal, it is easily soluble in weak acids, and even decomposes boiling water, so that its protective influence does not last long under such condition. Hence, for water pipes, cisterns, and especially steam boiler tubes, the protection afforded by galvanising is not likely to last long. The protection depends upon the thickness of the coating. It must also not be forgotten that zinc is a poisonous metal, and for that reason should not be used for drinking water tanks or service pipes, especially for waters which contain much chlorides. Electro-deposited coatings of other metals, such as copper and lead, are also used for the protection of iron and steel plates.

For structures exposed to the atmosphere, by far the most widely adopted and convenient method of protection is by painting. Paints for ironwork may be divided into two classes (1) varnishes, containing no pigment, generally solutions of bitumen, coal-tar pitch, stearine pitch, or wool pitch in tar oils, and (2) true paints, composed of a finely ground pigment suspended in a vehicle which is generally linseed oil. The number of such paints and varnishes is legion, and as each one according to the statement of the vendor is "perfect" they must all be equally good, and therefore I am spared the necessity of entering further into their individual merits and comparing one with another. I think our time may be more usefully spent in discussing broadly the features of a good protective paint and the conditions essential for success. Of first importance is the preparation of the iron for the priming coat. I am considering here new ironwork, and not work which has already been painted. The sooner the iron receives its priming coat the better, and the greater the care and attention bestowed upon this priming coat the better will be the result for ever after. I think this is perhaps the reason why the stencil marks upon girders and such like are frequently cited as testimony to the value of white lead. They are put on while the girder is new, even hot, and quite dry, and they can be still found underneath the subsequently applied paint when it flakes off or is scraped off for repainting. The iron for the priming coat should be quite dry, preferably even warm, so as to ensure dryness, and free from every trace of rust. Some engineers allow the iron to rust in order to remove mill-scale, but it is safer to remove the mill-scale by sand-blasting or wire brushes rather than allow rusting to commence. Rusting involves pitting, and unless the rust is scraped out of the pits down to the bare metal, a difficult and expensive process, rusting will go on underneath the paint. In experiments conducted with a great many well-known paints and varnishes I have found nothing better for the priming coat than genuine red oxide of lead—"red lead" —and genuine boiled linseed oil.

The lead and oil should be ground together in a mill—not merely mixed by stirring—and should be of such consistency that when painted upon a vertical surface the paint will not run down. This, of course, means a fairly thick paint, and one that requires the expenditure of a liberal amount of "elbow grease" in its application. For it needs to be well spread with a good brush, not merely daubed on, but well worked into the corners and crevices, and not too thickly. I would employ the best workmen in putting on this priming coat, working under rigid inspection, and

* Mitt. aus. dem. Koniglichen Material-prüfungsamt, Berlin, 26 (1908) 2.

allow three or four days for the paint to thoroughly dry. The contractor's men can then come along and put on the subsequent coats, which can be of any desired colour and almost anybody's "anti-corrosive paint." The priming coat should contain no drier, it is not needed, and no turpentine or other spirit, nothing but genuine red lead and genuine boiled linseed oil.* The so-called "drying" of linseed oil is, of course, a misnomer. The oil does not dry in a sense that a water paint dries, by evaporation of water; linseed oil dries by absorption of oxygen, which converts the fluid oil into a solid elastic skin of oxidised oil, and it is not desirable that any turpentine or other volatile spirit should be present which would evaporate and impoverish the skin. I am not a believer in tar varnishes for exposed ironwork. They all tend to harden and become brittle; at least this is my experience of such as I have tried. Neither have I yet found any oil to take the place of linseed oil. There are, of course, many other drying oils, and a very few, such as poppy and hempseed oils, can be used for painting, but at the present time suitable oils of this class are not available commercially, though they no doubt find their way into linseed oil as adulterants.

Every dry paint film is composed (1) of the pigmentary particles, and (2) of the oxidised oil varnish which cements the particles together and sticks them on to the surface which has been painted. It is important to remember that oil films are by no means impervious to gases or to water vapour. Many ingenious experiments have been made in order to measure the relative permeability of dried oil-films, by stretching them over bottles containing hygroscopic substances and noticing the relative increase of weight from time to time. It has been shown in this way, that under the conditions which usually apply in painting, genuine boiled linseed oil gives a film more impervious to water than any other oil tested, but that the addition to the boiled oil of 0·5 per cent. of paraffin wax reduces the permeability by one-half, without appreciably reducing the rate of oxidation or "drying" of the paint. To show what this may mean in the protection of ironwork from rusting, Friend† took three strips of pure iron foil, polished them, and coated one with a mixture of boiled linseed oil and tung oil, and another with the same oil in which 0·5 per cent. of paraffin wax had been dissolved. When the oil films had dried, the three pieces of foil were suspended in tap water for 31 days and then cleaned, dried, and weighed.

The unprotected plate had lost	0·502 gramme.
The plate coated with oil	0·189 ,,
The plate coated with oil and wax	0·089 ,,

This is a point worthy of attention by engineers.

Turning now to the pigmentary part of the paint film, R. Job, in a paper read before the Franklin Institute in 1904, showed the importance of excessively fine grinding of the pigment. The particles should be small, not exceeding one-thousandth of an inch in diameter, and of uniform size, in order that the film may be filled as completely as possible with the pigment, and the particles packed together as closely as possible, leaving no free oil spaces through which water can obtain access to the surface underneath the paint. You will see from these brief remarks how many factors enter into the successful protection of iron and steel work by painting, yet I am afraid painting is frequently looked upon as a very simple process, and that the main point to be considered is to get it done as cheaply as possible.

In places where water lodges, such as the bottom flanges of the girders of bridges, there is probably no better protective than Portland cement with which the hollow spaces can be filled, as recommended by Marriott,‡ but if used as a wash Portland cement lacks adhesive power and flakes off. In damp situations, therefore, such as the undersides of railway bridges, protection by painting becomes more difficult, and it is especially in such places that a good priming coat on the new material will repay all the trouble spent over it.

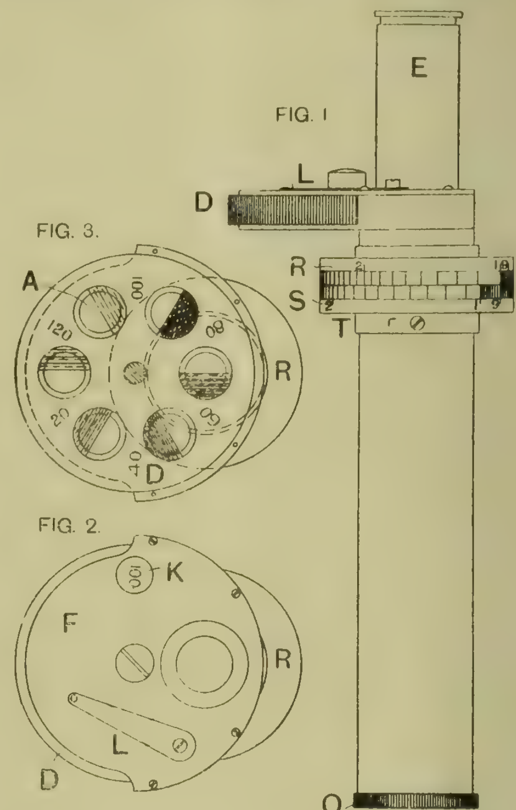
In a recent number of the "Zeitschrift fur Electrochemie" an account is published of some experiments by two German investigators, Leibreich and Spitzer, leading to the remarkable conclusion that, other things being equal, a single coat of paint affords better protection than two coats, and that an increase of the number of coats accelerates the corrosion of the painted iron surface. No satisfactory explanation has been suggested of this remarkable fact. It will no doubt be put to the test of practice, as the prospect of being able to save money and at the same time improve the value of the work is too good to be neglected.

(*To be continued.*)

* Gaston Despierres recommends orange lead in preference to red lead—it is lower in specific gravity and more finely divided. This is a point worth noting.
† Iron and Steel Inst. Carnegie Research Memoir. 1911. Vol. 3, p. 1.
‡ Proc. Inst. of Civil Engineers, Vol. 162 (1905).

OWENS' SMOKE-DENSITY INDICATOR.

IN instruments for measuring smoke from factory or other chimneys by comparing the opacity of the smoke with that of smoked glass, or other partially transparent substance, it is usual to view the smoke through an aperture in the instrument and match its opacity with one of a series of smoked glasses which may be fixed in a revolving disc and observed through a second aperture. In such instruments it is found that there is an error in the observed shade of the smoke and glasses due to the fact that when the eye is focussed on the smoke at a distance the edges of the apertures in the instrument are ill



OWENS' SMOKE-DENSITY INDICATOR.

defined so that the smoke and smoked glasses may both be seen overlaid by a haze due to this cause. To overcome this defect Mr. John S. Owens, 47, Victoria Street, Westminster, London, in the indicator illustrated herewith places the graduated smoked glasses and the aperture for viewing the smoke through in the optical system of a telescope in such a position that the edges of the aperture, the smoke glass, and the smoke examined are all in focus at the same time. This results in the aperture being seen with well defined edges and thus no haze overlies the smoked glasses, which can consequently be compared with the smoke without error due to the above cause. The smoked glasses are numbered in the ratio of their densities.

Fig. 1 shows a side view of the instrument, Fig. 2 a view from the eye piece end, and Fig. 3 a view of the eye piece end with eye piece and front of casing F removed so as to show the disc D. A telescope is provided having an object glass O and an eye piece E, and fixed in the telescope at a point which may be brought into the focus of both object glass and eye piece is a revolving disc D fixed eccentrically to the axis of the telescope and containing a number of graduated smoked glasses A arranged in cells around the centre of the disc D, so that when it is revolved any cell with its glass may be made to

occupy a position with its centre in the axis of the telescope and in the focus of both object glass and eye piece. The disc revolves in a casing F and is provided with a spring stop L to assist in bringing each cell into the axis of the telescope when required. In each cell is fixed a semi-disc of smoked glass A so that one half of the cell is filled with smoked glass and the other half empty. The smoke is observed through the empty half of the cell and matched with the smoked glass in the other half. A small hole K in the casing F of the disc D permits the observer to read a number on the disc D representing the density of the smoked glass which is in the axis of the telescope. In graduating the smoked glasses a unit of density is chosen representing the same opacity as unit density of smoke would when viewed through unit thickness, then the lightest glass is made of a density 20 times the unit density, so that a column of smoke 20ft. thick which matched in opacity this glass would be composed of smoke of unit density. The glasses are numbered 20, 40, 60, 80, 100, and 120, that is in the ratio of their densities or of their thickness if the same glass is used ; hence in any case the number of the glass matching the smoke when both are viewed by transmitted light will, when divided by the thickness of smoke looked through give the density of the smoke in the units chosen. Fixed on the tube of the telescope are two rings R and S. The ring R is fixed rigidly to the telescope, the other S is capable of being revolved and is held in place by a collar T. The circumferences of these rings are marked in logarithmic divisions so as to operate as a slide rule and permit of division or multiplication being done by their means.

ELONGATION IN 8in. AND 2in. BARS.

BY E. F. CONE.

There has always been considerable uncertainty about the relation between a 2in. and an 8in. test bar as to their elongation. The question is: What elongation in 2in. is the equivalent of 20 per cent. in 8in.? It has many times been desirable to make the tests in 2in., though a given specification called for the tests in 8in., the 2in. test being not only quicker and less expensive, but also the standard test. Accordingly tests were made to determine this relative value. Test bars 3in. by 1in. by 14in. long were cast on several large marine castings, and after the castings had been thoroughly annealed the bars were removed. From each bar there were cut an 8in. and a 2in. test. The physical results obtained in each case were as follows :—

Test.	Heat.		Elastic Limit, Lbs.	Tensile Strength, Lbs.	Per Cent. Elongation.	Per Cent. Red. Area.
A	1	8″	33,200	68,200	22·75	45·33
		2″	36,000	70,500	26·50	38·80
B	2	8″	34,000	67,600	21·75	46·25
		2″	34,600	71,000	29·50	41·90
C	3	8″	35,400	70,400	20·75	41·57
		2″	37,000	72,500	27·50	35·70
D	4	8″	32,200	68,200	21·25	38·64
		2″	35,000	70,000	26·00	41·90
E	5	8″	34,600	67,200	23·50	38·64
		2″	35,500	68,500	25·50	38·80
F	5	8″	34,800	66,200	21·50	36·67
		2″	35,500	70,000	26·00	40·30
G	6	8″	35,600	69,000	22·00	47·17
		2″	37,000	70,000	28·00	45·40
H	6	8″	33,600	68,000	18·00	*25·23
		2″	37,000	70,500	26·50	41·90
I	6	8″	33,400	67,600	22·50	42·52
		2″	36,500	72,000	27·00	38·80
J	6	8″	33,400	69,000	22·00	45·33
		2″	36,500	72,000	25·00	40·30

* Flaw.

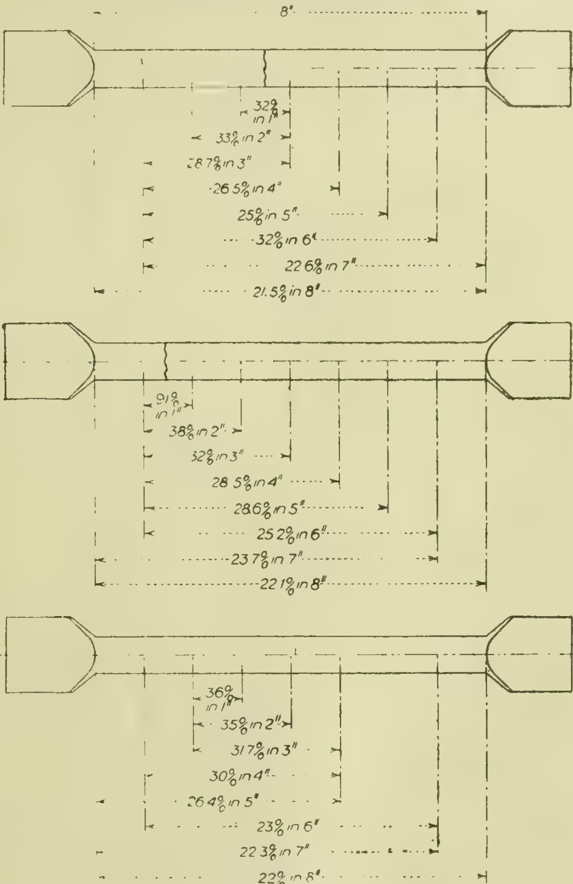
It will be noticed that there is an increase in elastic limit of 5 to 6 per cent. in the 2in. bar over the 8in. bar; in tensile strength of 3 to 4 per cent. ; in elongation of about 25 per cent. But in reduction of area there is a slight increase in the 8in. bar over the 2in. From these data it is deduced that when specifications for cast steel call for an elongation of 20 per cent. in 8in., the 2in. test equivalent to this should show 25 per cent. elongation on ordinary mild annealed cast steel.

At the time these tests were made three of the 8in. bars were laid off in inches, and the elongation in each inch measured. The accompanying cut shows the results of these measurements, and is rather interesting.

Analysing the preceding table, we find:—

	Elastic Limit.	Tensile Strength.	Elongation.	Reduction of Area.
A	2,800 +	2,300 +	3·75 +	6·55 —
B	600 +	3,400 +	7·75 +	4·35 —
C	1,600 +	2,100 +	6·75 +	5·87 —
D	2,800 +	1,800 +	4·75 +	3·26 +
E	900 +	1,300 +	2·00 +	0·15 +
F	700 +	3,800 +	4·50 +	3·63 +
G	1,400 +	1,000 +	6·00 +	1·77 —
H	3,400 +	2,500 +	8·50 +	15·67 +
I	3,100 +	4,400 +	4·50 +	3·72 —
J	3,100 +	3,000 +	3·00 +	5·03 —
Average	2,040 +	2,560 +	5·15 +	4·55 —

\+ = increase of 2in. over 8in. tests.
— = increase of 8in. over 2in. tests.



Elongation per Inch in 8-inch Test Bars.

This investigation was made at the request of the Bureau of Construction and Repair, United States Navy, and the tests were all made under the direction and scrutiny of a representative of the bureau.—" The Iron Age."

Manchester Association of Engineers.—On Wednesday, June 26th, the members of the Manchester Association of Engineers visited Rugby, with the object of inspecting the extensive electrical engineering works of the British Thomson-Houston Company, Ltd. The party left Manchester by the noon train for Rugby—luncheon en route—and on arrival was received by the principal officials of the company. Amongst the chief manufactures upon which the firm is engaged are turbines and accessories for the equipment of tramcars, and somewhere about 4,000 hands are employed. After being conducted through the vast works afternoon tea was served to the visitors, during which the president (Mr. Charles Day) took the opportunity of expressing their thanks for the courteous way in which they had been received by the company. Mr. Gregory, in responding, stated that the works were in a prosperous condition and very busy. As far as he could see the future was full of pleasant auguries, which, to a great extent, was due to the cordial co-operation of the staff throughout the works—to his mind a very important factor in workshop management.

HOLZWARTH'S GAS TURBINE.

THE gas turbine illustrated herewith, designed and patented by H. Holzwarth, of B.7. 18, Mannheim, and E. Junghans, of Schramberg (Wurtemburg), is of the type in which a combustible gaseous mixture is periodically exploded in separate chambers, the resulting gases then flowing with expansion into the actual turbine, whereupon the explosion chamber is again filled with the combustible mixture, after having been first scavenged with air, which has a cooling action. Fig. 1 is an axial section of the gas turbine; Fig. 2 is a section on the line A—B of Fig. 1, of the member closing the outlet of the combustion chambers; and Fig. 3 is a section on the line E—F of Fig. 2.

The combustion chambers, several of which are located adjacent different parts of the periphery of the running wheel C are indicated at D. They are provided with inlet valves G for air, and H for gas, and also with ignition devices J. A body K, which contains the nozzles L through which the com-

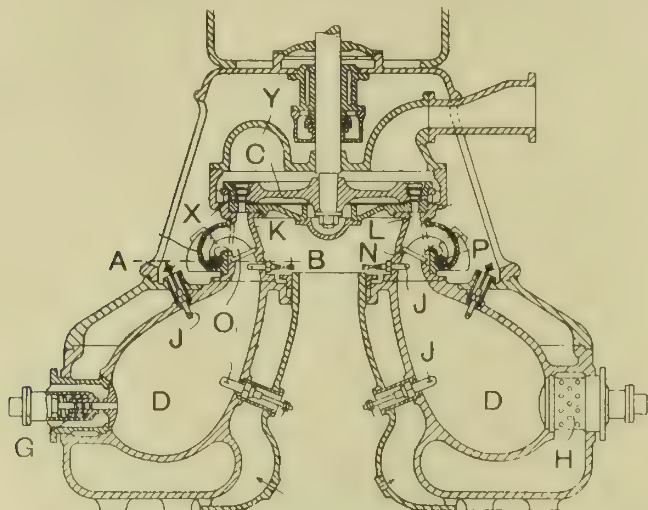


FIG. 1.—HOLZWARTH'S GAS TURBINE.

bustion gases expand before reaching the running wheel C of the turbine, connects with the outlet side of the combustion chambers D. A seat N is provided in the body K for a valve O which closes the passage from the combustion chambers D to the nozzles L. The areas of the sections of the passage at different points have of course a certain relationship to one another determined by the condition of the flowing gas in each section in view of the continuity of the flow. Preferably the area of the section of the passage at the seat N of the valve O, the area of the narrowest section or throat of the nozzle and the area of that section which the gas jet passes immediately before escaping, are in the proportion of 4 : 1 : 2, the lowest admissible value for the ratio of the first two areas being 4. The smallest nozzle section is at least $\frac{5}{1000}$ of the volume of the hollow space of the explosion chamber, divided by the diameter of a sphere of a volume equal to that of the explosion chamber. The other sections are wider in accordance with the abovementioned considerations, all the sections being thus of substantially greater area than has hitherto ever been proposed or used.

The body K contains all the outlet passages for the separate explosion chambers D and all the nozzles L, and is made as a single ring which is mounted on the base of the machine, which base contains the combustion chambers D. The valves O are each revoluble on a shaft P lying out of the way of the hot gases of combustion and may, as shown in dotted lines in Figs. 1 and 3, move so far aside when the outlet passage is opened, that they no longer impede the flow. They are made self-closing, being pressed on to their seats by means of a spring R and may be lifted off their seats against the pressure of the spring by the pressure of the combustion gases. This spring is located in a recess in the valve casing S, one end being connected with the spindle P of the valve O, whilst the other end is secured in the casing S. This casing forms a separate body which is placed at the side of the body K. In order that the closing valve may be controlled, for instance in order to maintain it in an opened condition, even after the pressure of the gases of combustion has considerably decreased, a separate chamber T is provided in the casing S and closed on the outside by a cover. In this chamber is arranged a closely-fitting rotary piston U which is mounted on the spindle P of the valve O. Any suitable fluid under pressure, for instance oil, may be admitted behind the piston U through a passage V, so as to propel the piston into the position shown in chain dotted lines in Fig. 3, so that the valve O assumes the position shown in chain dotted lines in Fig. 3.

The details of construction of the turbine can of course be carried out in various ways. It is particularly important, however, to give large dimensions to the outlet aperture from the combustion chambers. It is of especial advantage as regards this to form the closing member of this outlet as a flap valve instead of a mushroom valve, whereby a larger section of passage without substantial change of direction is provided for the combustion gases passing through it, and without the disadvantage that the operating parts must be placed in the path of the hot gas. A further advantage of the controlled closing member described is that the dimensions of this closing member and the parts belonging thereto may be kept comparatively small in spite of its wide opening, so that the valve gear may be affixed easily and without interfering with the appearance of the engine as a whole, and the closing member with the parts serving for operating it may be easily removed when necessary.

The object of keeping the initial temperature of the exploded mixture low is also substantially assisted by a further improvement which will now be described. In gas turbines of the kind previously referred to air is preferably sent through the gas turbine as a cooling medium in the same course as that which the propelling gases take. This is effected by admitting air to the combustion chambers D through the air inlet valve G in the intervals between the separate explosions, and discharging it through the nozzles L when the nozzle closing member O is opened. For imparting motion to this cooling air, of course, only as small a drop of pressure as possible should be employed for practical reasons. This drop of pressure should, however, suffice to convey the air through the same course which the expanding gas jet has previously taken. The expanding gas jet, however, moves at a very high velocity and the air jet at a very low velocity in consequence of the fall in pressure being only small, and the passages between the blades of the wheel C must be of such dimensions that they afford no appreciable resistance to the passage of the gas jet. Now the shapes, dimensions, and relative positions of the vanes cannot also correspond to the low speed of the air current and therefore they oppose great resistance to the movement of this current. In the arrangement under notice, a sufficient discharge for the cooling air is afforded without affecting the cooling action, by outlet apertures X for the air being provided in proximity to the first ring of blades on the running wheel, which apertures allow the air to escape from the space between the nozzle and the first

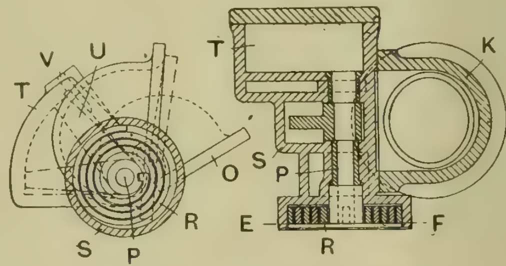


FIG. 3. FIG. 2.
HOLZWARTH'S GAS TURBINE.

ring of blades directly to the space Y beyond the turbine wheels, avoiding the passages between the blades of the turbine. In consequence of the radiating action of the running wheel not only is the running wheel itself sufficiently cooled, without the cooling air passing through its vanes, but also by the centrifugal action the conveyance of the air is considerably facilitated. The passages X are made as wide as possible and they extend so far over the periphery that they approach one another as closely as possible. The partitions separating them are tapered towards the inlet apertures and also towards the chamber Y.

ANNUAL REPORT OF H.M. ELECTRICAL INSPECTOR OF FACTORIES.

THE report of Mr. G. Scott Ram, H.M. Electrical Inspector of Factories, for the year 1911, just issued, is an interesting document and conveys a number of instructive lessons to all engaged in the design, construction, and use of electrical machinery.

The number of mechanical accidents was, he says, about the same as in previous years and calls for no special comment, but the number of electrical accidents, he continues, was somewhat greater—74 against 58 last year—the number of fatalities, four, being the same. With few exceptions the causes of the accidents were similar to those which have been described in detail in former reports. Under the first heading several were due to mistakes on the part of the switchmen, in some cases showing carelessness or incompetence. The next class of accident—through working on live switchboards or other live apparatus or conductors—is often due to carelessness on the part of the responsible person in charge of the work, or of the injured person himself, frequently by omitting to observe the most elementary precautions. In working on a dead portion of a high-tension switchboard, adequate screening of adjacent live conductors is not always provided. In some cases, although ample screening has been provided in respect of persons working from the floor level, it has been overlooked that the work might necessitate the person getting on to a higher level for some purpose, and so being close to live conductors which were out of reach from the floor. In one of these cases the man received a shock and severe burns from a 6,000-volt system. He was rendered insensible, but was brought round by artificial respiration, and was able to return to light work in about six weeks. In another similar case, the man was killed outright on a 20,000-volt system. Screens were actually provided in this case and were lying on the floor unused. The actual work in hand was upon some apparatus about 2ft. or 3ft. from the floor. There were live conductors above, about 8ft. 6in. from the floor. It was overlooked that in reinstating the apparatus a man might climb on to a part of it and so be within reach of the live conductors.

TABLE I.—*Accidents at Electrical Generating Stations and Sub-stations in* 1911.

The small figures relate to fatal accidents, and are included in the principal figures.

Description. (1)	Public supply stations and Electric railways and tramways. (2)	Other stations. (3)
Non-electrical :—		
At engines, pumps, and generators	18	4
At boilers and steam plant	39	6
At coal handling plant	18^{1}	3
Falls	76^{5}	8^{1}
Struck by falling bodies	28	—
Miscellaneous	91^{1}	17
Total	270^{7}	38^{1}
Electrical :—		
At switchboards when engaged in ordinary routine work—mostly due to faulty design of apparatus or to mistakes on the part of the switchman.	12	5
Cleaning, repairing, &c., at "live" switchboards or other "live" conductors.	27^{3}	2
Cleaning, repairing, or other handling of switchboards supposed to have been "made dead."		
Skilled persons	3^{1}	—
Unskilled persons ..	—	—
Adjusting brushes and cleaning commutators	9	3
Miscellaneous	12	1
Total	63^{4}	11

Several accidents occurred in cleaning extra high-tension switchboards. In one case, in a sub-station, a cell had been made dead and the door opened for cleaning. A second door was then opened before the conductors had been made dead. The cleaner went into the second chamber and received a shock between his hand and neck. A heavy short circuit occurred, bringing out the circuit breaker at the generating station. The man was badly burned and was rendered insensible, but was brought round by artificial respiration and was able to return to work in a few weeks. In another case, in a generating station the switchboard was arranged in two sections, so that either could at any time be made dead for cleaning or other work, but was not otherwise sub divided. There was an inter-connecting switch at the end of one section, but not screened off. This switch could have been made dead by means of isolating switches in the gallery below, but this had not been done, and it was therefore live on one side. The man who was cleaning, who was also a switchboard attendant, touched this switch, and although severely injured by shock and burns, his right arm having to be amputated at the shoulder, he escaped with his life. In subsequent legal proceedings, the responsibility for the accident was held to lie with the injured man himself for going into the chamber while the inter-connecting switch was live. In another case, a man was cleaning insulators with exposed conductors at extra high tension close by. He was severely injured, but not killed. In another, a sub-station attendant received a shock at extra high pressure, apparently through his own fault in not making sure whether the current had been switched off at the generating station end of the line before starting to clean the apparatus. Another high-tension accident occurred to a man working in a switchboard cell, and appears to have been due to the stupidity of the man in charge in allowing the pressure to be turned on before the work was completed. In another case, a "competent" man was fixing a guard at some high-tension apparatus with wire. As might have been expected, the loose end made contact with a live conductor. In the second fatal case a competent and experienced man appears to have forgotten that the oil switch which he was examining was live, and touched one of the terminals. It is remarkable that of the above nine accidents on high-tension or extra high-tension alternating systems, only two had fatal results.

Several accidents occurred through men making short circuits on direct-current medium-pressure systems. Some were due to the omission to take any kind of precautionary measures. Thus, ordinary engine-room spanners were used in several cases to tighten up nuts at the backs of switchboards, no precautions by screening or otherwise being taken, the spanner being applied to a live nut on one pole, bare bus-bars or other conductors on the other pole being only a short distance away—less than the length of the spanner. The extraordinary thing is that such things are done by switchboard attendants of experience. Much of the blame often, however, lies with the employers or their responsible engineer in not providing special insulated spanners or other forms of temporary protection in view of work on live conductors becoming necessary. In one case, two assistant engineers proceeded on the above lines to tighten up a live nut on one of the main connections behind the bus-bars at the back of the switchboard and produced the inevitable short circuit. They were both burned, but not very badly. The short circuit apparently produced a surge with probably a big rise in the pressure on the breaking of the short-circuit current, with the result that a flash-over occurred at another part of the switchboard several feet away, at a place where the positive and negative conductors on a marble panel were barely 1in. apart, without any insulating division between. The normal difference of pressure between these conductors was 580 volts, and although this would be a long way below that necessary to start an arc between conductors in air, it might conceivably do so without difficulty if dirt or dust were allowed to accumulate on the surface of the marble. There is no doubt, however, that on the breaking of a very heavy current such as would be caused by a short circuit on a station switchboard with 2,000 kw. or 3,000 kw. behind it and with no circuit-breakers on the generators, a very great momentary rise in pressure might occur. On 550-volt traction switchboards it has been proved that the operation of a feeder circuit-breaker on heavy overload may produce a momentary rise of pressure of over 10,000 volts. The design of the switchboard, with the main conductors placed so closely together, was obviously at fault, as even under normal conditions accidental short circuit might be readily brought about, and the mere cleaning of the surface of the marble between the conductors would be a hazardous undertaking. The above accident had a very unfortunate

sequel a few hours later. The switchboard attendant noticed that at the place where the arcing-over had occurred, there was a slight discharge going on across the marble between the positive and negative conductors. This may have occurred through a film of copper having been deposited on the marble at the time of the flash-over. He reported the sparking to the station superintendent, and while the latter was looking at it, it again developed into a flash-over or short-circuit, with the result that the superintendent was so severely burned that he died within a few hours.

Under the next heading, the fatal accident occurred to an experienced man who was about to do some work in a cell of a single-phase high-tension switchboard. The system had one pole earthed, and the switchboard was a single-pole one. The cell contained an oil switch for a generator. The switch was connected directly, and not through isolating switches, to the ring bus-bars of the switchboard. The bus-bars were, however, provided with a number of disconnecting links in order that any circuit might be isolated by removing the link on each side of the point where it connected with the bus-bars. The man had removed the links on each side of the connection to the switch at which he was intending to work. Unfortunately the system of disconnecting links had not been adhered to when extensions had been made. A generator placed at a later date in another engine-room had been connected to the same part of the bus-bars. The removal of the two disconnecting links did not therefore disconnect the second generator from the switch cell in question. This second generator happened to be at work, and although it was connected to the bus-bars through an oil switch, the man appeared to have forgotten the arrangement of the connections and omitted to pull out the switch. He consequently opened the door of the switch cell of the first generator, thinking it was all dead, and received a fatal shock. The accident appears, therefore, to have been in part attributable to the connection of the subsequent generator with the bus-bars not having been carried out on the same lines as those of the other circuits. The design of the switchboard was such that the connections could not be readily traced. It is important with all such switchboards, where the connections are not visible or obvious, that a diagram of the connections should be hung up in the switch-room for ready reference before any work is undertaken. A useful precaution adopted in many stations is also recommended, namely, that a second competent person should check the position of the switches and isolating links before any work is commenced.

Of the miscellaneous accidents, several occurred to unskilled persons and were due to lack of proper supervision. Four occurred on extra high-tension systems, and were remarkable only because the injuries did not prove fatal.

TABLE II.—*Electrical Accidents in Factories other than Electrical Stations in 1911.*

Arcing of switches	37
Arcing of fuses	10
Shock or burns from fuses when replacing fuse-wires	28
Portable apparatus, connectors, and flexible wires	62[2]
Unprotected conductors, switches, terminals, fuses, &c.	23
Working on or near live conductors—skilled persons	41
Working on or near live conductors—unskilled persons	24
Miscellaneous accidents in electrical manufacturing works—mostly in testing operations	36[1]
Adjusting brushes and cleaning commutators	2
Miscellaneous	27[4]
Total	290[7]

These accidents show a slight increase in number over those of the previous year—290, as against 276—whilst the fatalities were 7, as compared with 5 in the previous year.

Of those caused by the arcing of switches, a number on motor circuits were as usual primarily due to the previous failure of the no-voltage release on the starting switch, so that the main motor switch was put in on a short-circuit, producing a heavy arc at the contacts. In some cases the switches were protected by covers having a slot for the handle to work through. This form of cover is the only one which can be applied to certain types of switch, and while it is satisfactory in preventing the operator from touching live metal, it does not protect the hand from being burned if a heavy arc occurs within the cover, unless there is in addition a shield on the handle. Accidents from the arcing of fuses are due to absence of adequate protection. Some enclosed or cartridge-type fuses which will operate satisfactorily on a moderate overload will explode violently on a short circuit, and need protection as much as bare fuse wires.

Many of the accidents in the renewing of fuses were with the primitive type of bare wire or strip-metal fuses directly connected to the live fuse terminals, and unprotected by a switch. Short circuits were made with screw-drivers or by the fuse metal getting across both poles. In some cases, switches were provided for cutting off the pressure, but were not used. In one case the man took hold of a live fuse terminal, 220 volts alternating, and was unable to leave go until pulled away by some one else.

The 62 accidents in connection with portable apparatus were mostly due to short circuits, causing burns. In 24 cases the short circuits were in the flexible wires, and were due to the covering of the wires having been damaged, or to the fact that the wires were insufficiently protected in the first instance in view of the rough treatment to which they would be subjected in ordinary use. In 21 cases the short circuit occurred at the connector plug, and under circumstances where the accidents would have been prevented by the use of plugs constructed with hand shields on the lines which I have described in former reports. Several were caused through connecting hand lamps and even drills, taking a considerable amount of current, by means of "adapters" to ordinary lampholders. There were also several cases of shock received from portable drills which were leaky, and had not been earthed. The two fatalities occurred through the use of unearthed and improperly-constructed hand lamps. In the first case an ordinary switch lampholder was connected by means of flexible wires and an "adapter" to the lighting system. The pressure was 250 volts direct current from a public supply, and the lampholder was not earthed. The lampholder was through some defect "live," and the man holding it was in connection with earth. He was washing out a metal vat with a hose pipe, and was standing on wet steps. He called out three times, and a boy ran to his assistance, and received a shock in trying to pull the lampholder away. Unfortunately in this case artificial respiration was not attempted. In the other fatal case the victim was grasping a hand lamp of old pattern, having the lampholder in connection with the other metal work, which was not earthed. The current was alternating 220 volts.

The accidents due to unprotected conductors do not call for any special comment. Several occurred in shipyards on ships under construction, and where there is much temporary wiring, the insulation of which is very apt to get damaged.

The accidents to skilled men, *i.e.*, "electricians," when working on live conductors are frequently inexcusable, the men taking unnecessary risks of which they are fully aware. In some cases they have not taken the trouble to switch off the pressure, and in other cases the work might have waited until after factory hours, when the whole installation, or at anyrate the particular circuit, could have been made dead without inconvenience. The similar accidents to unskilled men, *i.e.*, not having technical knowledge, were in several cases due to the stupidity of, or want of proper supervision on the part of, the electrician in charge of the work. In some cases the men attempted to do some work entirely on their own responsibility, and in others they were employed on work for which they were not technically competent.

The accidents occurring at the works of electrical manufacturing firms were nearly all in the testing departments, and, as usual, many occurred to apprentices and the like. The average age of 32 of the 36 persons meeting with accidents was only 21 years. As I have before pointed out, employment in the testing departments of such works is given greatly to young fellows on leaving technical colleges, and who desire it in order to gain experience. Several received shocks at high pressure. The fatal case occurred in a large testing shop, and was due to a mistake in connecting up two high-pressure machines with the same set of conductors and artificial load, one set of men apparently not being aware of what the others

were doing. One machine was started up, and a man working on the other received a fatal shock.

Under the heading "miscellaneous" there were four fatalities. One occurred at a shed of an electrically-operated railway, the man climbing on to the roof of a carriage, apparently forgetting that the high-tension overhead wires were live. The second occurred in a shipyard to a man working a large outdoor radial drilling machine, which was driven by a 3-phase 440-volt motor bolted to it. The machine was fixed to an upright baulk of timber, and was not earthed. A leakage occurred at the motor, and the whole machine, together with the metal plate being drilled, and which rested on timber, became electrically charged. The man operating the machine was killed, and his helper, who went to his assistance, received a severe shock. The third fatality occurred to the driver of an overhead electric travelling crane in an engineering shop. He was attempting to get from one crane to another in the adjoining bay by climbing across a girder, above which the trolley wires were placed, and with which he appears to have come into contact. He was taking a short cut, instead of going down one ladder and up another. The fourth fatality occurred at the trolley wires of a dock crane which were on the ground and protected, except for a longitudinal slot in the cover, through which the collectors travelled. The man appears to have dropped something in the slot and to have put his hand in to try and get it out, and touched the conductors.

Prosecutions were taken for breaches of the regulations in reference to two fatal accidents and two non-fatal accidents. In the fatal cases convictions were obtained, and penalties of £50 and £10 with costs in each case were obtained. In the former case the amount of the fine was awarded to the widow. In the other cases a penalty of £1 and costs was obtained in one instance, and the other case was withdrawn on payment of costs by the firm, the Court deciding that the admitted contravention of the regulations and resulting accident were due to the wrongful action of the injured person himself.

(*To be continued.*)

CENTENARY OF GAS LIGHTING IN LONDON.

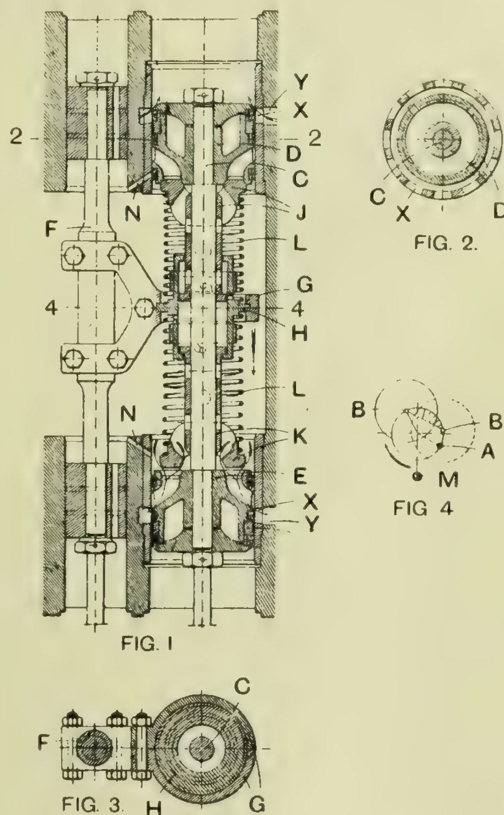
THE centenary of the Gas Light and Coke Company of London serves as an interesting reminder of the fact that it is only a hundred years since Parliament granted power to a company to supply gas to the general public in London. At the present day the opposition urged against the use of the new illuminant furnishes amusing reading, though we can well believe it must have been irritating to the men who had to engineer the scheme. It is curious to read, for instance, that opposition came from those engaged in the whale fishery, because they thought that the use of gas would destroy their livelihood. Sir Walter Scott ridiculed the idea, and a learned divine preached against it on the ground that it was the work of Satan, who wished to turn night into day. At that time there was much distress, and considerable rioting against scientific improvements of any kind. About 40,000 weavers were on strike, and the manual workers viewed with distrust mechanical inventions pretty much as many trade unionists do to-day, on the ground that they created unemployment. Perhaps some allowance must be made for these narrow views, for even so eminent a scientist as Sir Humphry Davy sarcastically asked if the scientific men would like to use the dome of St. Paul's Cathedral for a gas-holder. The manager of the company replied that one day they would be of equal size, and, as a matter of fact, before he died that size had been exceeded.

A Fast Turbine Yacht.—The turbine yacht "Winchester," built for Mr. P. W. Rouss, New York, by Messrs. Yarrow and Co., Glasgow, recently ran her full-speed trials on the Skelmorlie measured mile, attaining a mean speed of 32¼ knots. This was a quarter of a knot in excess of the contract speed. The "Winchester" is 205ft. in length, 18ft. 6in. in breadth. The trials prove her to be one of the fastest yachts afloat. The propelling machinery consists of Parsons turbines driving two shafts, and steam is supplied by two Yarrow water-tube boilers, fired with oil fuel.

AUXILIARY CONTROLLING VALVES FOR STEAM ENGINES.

AN arrangement for controlling the supply of motive fluid to the cylinders of steam engines, the invention of Messrs. Delaunay-Belleville, of Ateliers et Chantiers de l'Ermitage, Saint Denis, Seine, is shown in the accompanying illustration. It consists in the provision of an auxiliary valve operated by a separate eccentric, and which co-acts with the main piston valve in such a manner as to cut off the supply of motive fluid to the cylinder through the main valve at any predetermined point. Fig. 1 is a longitudinal section on the axis of the slide valve. Fig. 2 is a section of the slide valve on the line 2, Fig. 1. Fig. 3 is a section on the line 4 in Fig. 1. Fig. 4 is a diagrammatic representation showing the relative positions of the crank M, of the piston, of the eccentric A, of the slide valve, of the eccentric B, of the expansion member, and of its displacement from B to B¹. Figs. 5 and 6 illustrate the method of varying the keying of the eccentric.

The eccentric A is keyed in a fixed position and effects a fixed stroke; it controls the rod C, which in its turn operates the principal slide valve composed of two pistons D and E; these pistons thus controlled by the eccentric keyed in a fixed



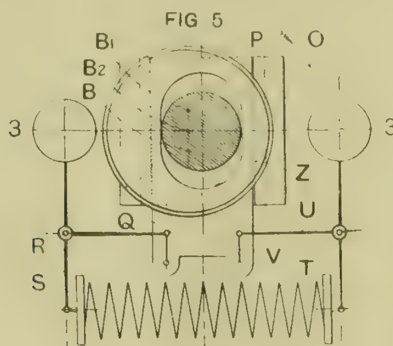
AUXILIARY CONTROLLING VALVES FOR STEAM ENGINES.

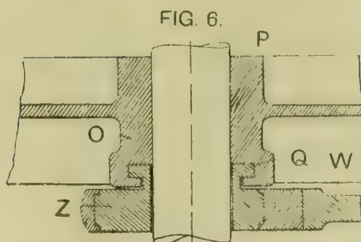
position are provided with junk rings. The other eccentric B is variably keyed, and in certain cases its stroke is variable. The rod F which the eccentric B controls carries at some point of its length the collar G in two parts, which embraces the member H; the latter drives alternately the parts J and K, connected with the part H by the springs L, and able to slide upon the rod C; they end in valves, which seat upon the pistons D and E. The variably-keyed eccentric which operates the rod F is displaced from B to B¹ (Fig. 4) in a straight line or in a curve, and this displacement is controlled by the governor of the engine.

In Figs. 5 and 6 the governing device is illustrated. Upon the shaft P there is fixed a frame O which rotates with it, the eccentric Z upon which a bearing W actuating the rod F is mounted participates in the movement of rotation of the shaft P. This eccentric comprises two ribs Q, displaceable in appropriate grooves or slots in the frame O, in order to modify the keying of the eccentric. To permit of this movement the eccentric has a recess therein, through which the shaft passes. In the case illustrated in the figures the centre of the eccentric

Z is at B^2, this centre being capable of displacement between the extreme positions B^1 and B. The balls of the governor are mounted at the extremity of levers which pivot around pivots R and rotate with the shaft P. The arms S are attached to the extremities of the spring T, which balances the centrifugal force. The arms U are jointed to two small rods V by the intermediary of which they act upon the eccentric Z and displace the ribs Q in the slots thereof. In proportion as the speed increases, the ribs Q move in the frame O, and the centre of the eccentric traverses the straight line B B^2 B^1. The result is an increase in the angle of keying, and the closing of the expansion orifice is advanced; there is also a diminution in the stroke from B to B^2 because the centre of the eccentric approaches the centre of the shaft. On the other hand, there is an increase in the stroke from B^2 to B^1.

The operation is as follows: The position B of the variably keyed eccentric is such that the valves J and K close the ports of the pistons D and E (which distribute the steam in the ordinary manner) only when these pistons themselves close the ports in the cylinder; the admission is the maximum in this position. The position B^1, on the other hand, is that in which no admission takes place, the valves J and K being always applied to their seats when the pistons D and E uncover the ports of the cylinder. In the interval between these





AUXILIARY CONTROLLING VALVES FOR STEAM ENGINES.

extreme points and in proportion as the expansion eccentric moves away from the position B and approaches the position B^1 the valves J and K close the ports in the pistons D and E increasingly early, thus progressively reducing the admission until the point B^1 is reached, where it is zero. It will therefore be understood that it is possible to vary the admission and the rate of expansion of the operative elastic fluids by employing the minimum number of parts compatible with the realisation of these desiderata.

In order to render the operation of the valves J K to be easily effected when the pistons reach the end of their stroke, that is to say, towards the moments at which these valves should open, the pressure is balanced on their two faces (outer and inner faces) by the reason of the small conduits N which enable the fluid to pass beneath the valves, these conduits being obturated by the packings of the slide valve as soon as the latter makes its retractive movement for producing the distribution. The member H which is formed in two parts has considerable longitudinal play during which it moves without displacing either of the two valves J and K, thereby enabling these valves to remain applied to their seats under the double action of the fluid under pressure, the admission of which they cut off and of the springs which are compressed by the member H in movement during the fraction of the stroke of the piston corresponding to the expansion period. The pistons D and E slide in special sleeves, presenting orifices X which correspond with the orifices Y of the cylinder.

THE CORE ROOM: ITS EQUIPMENT AND MANAGEMENT.*

BY HENRY M. LANE.

(*Continued from page 805, Vol. XXIX.*)

Action of Oil in Binding Sands.—Oil of a proper grade is undoubtedly the strongest and, weight for weight, the most efficient binder known when dealing with clean silica grains. In the paint trade linseed oil is considered the best drying oil, and it is also the best core oil. The action of linseed oil in bonding a core is as follows: The material must be so thoroughly mixed with the sand that every grain is uniformly covered with oil or an emulsion of oil and water. When the heat of the core oven acts on the sand the moisture is evaporated and driven off. As the moisture passes through the core towards the outside the oil remains behind on account of its relatively high viscosity, and first uniformly coats each grain of sand. By capillary attraction excess of oil tends to accumulate at the contact points of the sand grains, and finally dries down here and forms an area of bond somewhat larger than the contact points. The heavier the oil—that is, the more body it contains—the more will the space about the contact points be filleted and the bonding area increased. Most of the other drying oils contain less body than linseed, and hence do not give so firm a bonding mass at the contact points as is the case with linseed. All oil-sand mixtures must be tempered with water.

Action of Paste in Binding Sand.—The radical difference between the bonding of sharp sand with an oil and with flour or dextrine is that the latter forms small masses or grains of paste which dry on the face of the sand grains. These do not flow over it to the contact points, but dry in the place where they were left by the mixing machine. For this reason only those situated at the contact points become efficient as a binder. A microscopic examination of a flour or dextrine-bound core shows that certainly not less than 60 per cent. of the material is inactive as a binder, and is located in such a way that it tends to block the vent passages by giving the grains of sand a rough, instead of the smooth varnished surface given to the grains by oil.

Action of Resin and Pitch in Binding Sand.—Resin and pitch both bond sand by melting and flowing over or between the grains, collecting to a certain extent at their contact points as the core cools, but they are not so efficient as is oil. Resin and pitch do not enter into combination with clay, but their binding power is added to whatever power the clay may have. When such a core comes in contact with the molten metal in the mould, the carbon material of the resin or pitch is burned out, which disintegrates the core, thus making it possible to clean it from the casting; while if clay or natural bond alone were depended upon the bond would be hardened instead of softened, and it would be impossible to clean it from the casting.

Action of Molasses in Binding Sand.—The action of molasses in a core depends upon the rate of drying and the temperature. Under ordinary core-oven conditions where cores are put into a hot oven, the water is quickly expelled and the molasses brought to the boiling temperature. When it reaches the consistency of ordinary molasses candy, it boils up in a similar manner and then hardens in thin plates connecting the sand grains with a more or less intricate system, and with the carbon exposed in exceedingly thin surfaces, though, of course, some of it dries at the contact points. If the core is taken from the oven at the critical point just as these plates are in their strongest condition, it will be found to be strong and serviceable; but if taken out too soon, it will not have developed sufficient strength to give a strong core, and if left in the core oven a little too long the carbon will have become rapidly oxidised and the strength of the core will fall off. For these reasons a molasses core is exceedingly sensitive, and with ordinary existing core-oven conditions it is practically impossible to produce uniform results.

Action of Glutrin in Binding Core Sand.—The compounds contained in glutrin are of such a nature that they do not enter into and combine with clay as does oil, but they form with

* Abstract of paper read before the American Society of Mechanical Engineers.

it an exceedingly efficient emulsion and tend to carry it from the faces of the sand to the contact points. In drying, glutrin behaves more like oil in that it tends to flow to the contact points.

In sharp sand without any clay bond, the fact that glutrin lacks the viscosity of linseed oil gives it a tendency to follow the moisture to the surface of the core. In a mixture of clear, sharp sand a glutrin core will tend to have a very hard skin and a soft interior. The sweating tendency is entirely overcome by introducing from ½ to 1 per cent. of clay into the mixture, the clay and the glutrin together forming a compound which is sufficiently viscous so that it draws to the contact points rather than following the moisture to the surface of the core, making it strong and at the same time one which does not have the vent passages stopped. Glutrin can also be used in connection with oil in clear sand mixtures, as the oil prevents it from sweating to the surface of the core and the combination blends perfectly to form an efficient bond at the contact points.

An oil-sand core made from a mixture of 22 parts silica sand, three parts bank sand, and a commercial or blended oil at the ratio of 1 part of oil to 25 parts of sand has an exceedingly open character, and a strength of about 75lbs. per square inch in tension. A core of this kind shows absolutely no tendency for the binder to sweat to the surface, and as the sand from which the core is made is fairly uniform in size there is a maximum of voids or open spaces for vent passages.

In the case of a core made from gangway sand with glutrin as a binder, the glutrin sweated to the surface of the core, forming a hard skin. The interior of this core was so soft that it would readily crush before the metal. These cores were used to form finished faces for bearings in agricultural machinery, the cores being knocked out of the castings, the hole cleaned, and the parts assembled without machining. The fact that the glutrin sweated to the surface made a hard close surface which acted almost as a chill and produced a remarkably smooth casting. The rotten interior gave free vent. At another plant some cores were made from the same sand with linseed oil as a binder, but the binding ratio had to be very low, that is, a large amount of oil used to bind a given amount of sand. This was also true in the case of the glutrin.

Reactions Between the Sand and the Binder.—A quantity of gangway sand was shipped to the laboratory at Covington, and together with other sands that had been giving trouble a series of experiments was started. From the behaviour of these sands it was evident that some action was going on which destroyed the binder, other than the mere absorption of it, which takes place when the oil unites with clay and is rendered inoperative. To test the correctness of this theory a batch of gangway sand and a batch of Michigan City sand were measured and placed in two bottles. As glutrin was wholly water soluble it was chosen as a binder. Three equal batches of glutrin were diluted with a given amount of water. One was placed on the Michigan City sand, another on the gangway sand, and the third held in reserve. After leaving the binder several hours each sand was leached with water until all the binder was washed out. The two batches of glutrin were then concentrated by boiling to expel the excess water. They were brought to the same volume as the batch held in reserve, and three sets of cores made, one from the glutrin which had been on the gangway sand, one from that which had been on the Michigan City sand, and the third from that which had not been on any sand.

There was very little difference in the strength of the cores from the second and third batch, but the cores made from the glutrin which had been on the gangway sand were not one-fourth as strong as the others, showing that the sand had destroyed the bonding power of the glutrin. A few tests soon showed that it was alkaline, and the addition of a small amount of acid destroyed the alkalies.

Following up this clue, two batches of cores were made from gangway sand, in one case the sand having been treated with acid to neutralise the alkalies and in the other it was left in its natural condition. The acidulated sand produced cores more than four times as strong as the other batch. Continuing the investigation, experiments were made by treating with acids a number of sands giving poor results with different binders, and it was found that neutralising the alkalies with acids increased the strength of the cores greatly. This is true both in the case of glutrin and oil.

Since these experiments the subject has been taken up with a number of foundrymen and several exceedingly interesting cases brought to light. In one instance a foundry was purchasing city water of a very pure grade at a relatively high cost. To avoid this expense an artesian well was sunk. Immediately trouble appeared. The cores cut and washed, and it took some time to trace the difficulty. Finally the city water was again used, and the trouble disappeared. The water from this well was clear, sparkling, and tasted good, but it was high in lithia salts and evidently contained ingredients which combined with the binders to destroy them.

Alkalies tend to saponify oil, thus destroying its bonding power. They also seem to act on resin, glutrin, and some other binders. In the case of the large manufacturing concerns using a great many oil-sand cores it would probably pay to purify the water for the core room, just as the feed water is purified for the boilers.

Determining the Active Bond in Clay.—Formerly, when a chemist received a sample of sand for analysis he determined the alumina, figured it as kaolin, and called it "bond." From various results with bonded sands it became evident that this free and easy method was not sufficient, and some way of differentiating between a fat and a lean clay had to be found. Several firms and different departments of the Government were making use of a test for colloidal matter. Chemists have long recognised a series of amorphous bodies known as colloids, or as one noted chemist, writing in popular vein, recently says, what in the laboratory are called "messes."

When matter is in one of the colloidal forms it has intimately associated with it a large amount of water, forming what is termed a "gel." The soluble colloids are called "sols." Certain clays are far more plastic and have greater binding powers than others, and it has always been known that heat destroyed this binding power. It is now certain that in these clays at least a portion of the alumina is in the colloidal form. For decades the best clays have been found in the secondary deposits, where they had been associated with organic matter, but these properties have been found even in the old fireclays of the coal measures. When first exposed these are in a compact form, much of the water having been expressed or driven out by pressure, and when exposed to the weather they absorb moisture.

The only test for colloids of which there is any record is the one used by several departments of the Government and a number of firms in this country, and is founded on experiments carried on in Germany. The aniline dye known as malachite green is used for this purpose. A given amount of malachite green is weighed out and dissolved in 400 cub. cm. or 500 cub. cm. of water. Into this from 10 to 20 grams of the sand or clay to be examined is introduced, and the whole is shaken in a shaking machine for an hour. The bottle containing the material is then taken out and the solid matter allowed to settle to the bottom. A portion of the liquid above the solid matter is drawn off, placed in a colour tube, and compared with the dye diluted with the same amount of water which was used in making the original solution.

The amount of dye absorbed by the colloidal matter in the sand indicates the bond present in the sand. Table I. shows a series of colloidal readings on a group of sands examined under the direction of the author. A sample of kaolin was taken as 100 per cent., and other sands were compared by the amount of dye they would absorb. A number of clays have since been found that run considerably over 100 per cent. This scale has served to compare the different sands in the laboratory, but before a method of this kind becomes general throughout the country some standard should be fixed. The readings given in the table represent only a small portion of the determinations made. It will be noted that the materials may be grouped into three classes. The first three samples tested represent washed silica sands with approximately the same colloidal reading; the next five represent beach or lake sands from the shores of the Great Lakes. All of these are wind-driven sands with about the same colloidal reading. These are followed by five core

sands which would ordinarily be considered as fairly sharp. The first two are English core sands; the third is the Manistee sand as used at Flint and Detroit, Mich. The reading on the old moulding sand given fourth is not to be depended upon for its original colloidal reading, since the use of a sand always changes the colloidal content, the colloids themselves being usually destroyed. Burnt sand, however, generally contains material which will destroy the dye and so give an apparent colloidal reading. The old moulding sand really had very little bond, though the colloidal or dye reading would place it in a class having a fair amount. Another case of a burnt sand is given near the bottom of the table, this being the same gangway sand from Moline, Ill., with which the tests in acidulated sand were first carried on. There was absolutely no colloidal matter in this sand. This and other tests led to the belief that the dye reading was to be depended upon when applied to new sands in the condition in which they are dug, but does not apply to material which has been exposed to molten metal. The very high colloidal reading of Lumberton sand is to be expected, as this contains a very large percentage of clay.

TABLE I.—*Colloidal Reading on Sands.*

Name.	Bond No.
Washed silica core sand, Bethlehem, Pa.	2·17
Washed Ottawa silica sand, Ottawa, Ill.	2·30
Silica sand, Derby, England	2·50
Sharp sand, Faribault, Minn.	5·02
Core sand, Sauk Centre, Minn.	5·21
Michigan City core sand	5·27
Crystal Beach lake sand, Buffalo, N.Y.	5·30
Beach sand, Buffalo Am. Rad. Co	5·43
Core sand, Falkirk, England	10·66
Core sand, Falkirk, England	10·81
Manistee lake sand, Flint, Mich.	10·70
Old moulding sand, Faribault, Minn.	10·80
Silica core sand, Duquesne Steel Foundry Company	10·84
Mansfield core sand, Birmingham, England	15·38
Bank sand, Rochester, Mich.	21·63
New moulding sand, Faribault, Minn.	32·60
Gangway sand, Moline, Ill.	43·50
Lumberton sand, Hainesport, N.J.	53·43
Kaolin, Fimer, and Amend	107·60

The behaviour of many of the sands tested when made into oil-sand cores showed very conclusively that the dye test gives a good idea as to the amount of oil which would be destroyed by the sand. Apparently the dye reading gives not only the colloidal matter which will destroy the oil, but in the case of old or burnt sands gives a fair indication of the amount of alkali or other material present which would destroy the oil. This was noted in connection with the gangway sand from Moline. Further tests will be made along the line of examining sands and studying the relationship between the natural bonding power and the colloidal reading as given by the dye tests. Thus far this seems to be the best test found.

Action of other Binders on Oil.—When an oil is used as a bond it is not only destroyed by any clay or colloidal matter present, but may also be destroyed by other ingredients used as binders. Where green strength is required in a core, foundrymen frequently introduce flour or dextrine into oil-sand mixtures. The oil first combines with the flour to form an oil-flour paste which has very little bonding power, but when so held it is not in a position to act as a binder between the sand grains. In consequence, what happens in a mixture of this kind is that a portion of the oil unites with the flour and is itself destroyed for binding purposes. At the same time it renders the flour less efficient than it would be had it been mixed with water. The balance of the oil can act in its usual manner between the sand grains.

Testing Binding Power of Liquid Binders.—The final binding power of any compound is measured by the solid bond left in the baked core. Paint chemists test their oils by drying them down to a film and seeing what percentage of weight has been lost in this action. In the case of Table II., the binders shown in the column at the left were each weighed out into porcelain crucibles and first placed in an air bath and subjected to a temperature of 100° C., or 212° Fah., for 24 hours and then weighed. These results are entered in the second column. The crucibles were next placed in the core oven at a temperature of 400° for 1 hour and again weighed, and the results indicated in column 3. Some of the crucibles were then returned to the core oven for another hour, exposed to a heat of 410°, cooled, and again weighed and the results recorded in the fourth column. The samples were then all heated in the air over a blast lamp to burn off the carbon, and the percentage of ash is recorded in the fifth column.

TABLE II.—*Determination of Solids in Liquid Core Binders.*

Name.	Dried 24 hours at 212 Fah.	Dried 1 hour at 400° Fah.	Dried 1 hour at 410° Fah.	Burned to Ash.	Remarks.
Glutrin	51·47	41·98	—	8·03	Skin.
Raw linseed oil	100·22	96·98	95·22	0·22	No skin.
Boiled linseed oil	93·49	90·23	—	0·54	Skin.
Soya bean oil	100·91	96·45	94·26	0·65	No skin.
Fish oil	100·52	92·70	91·25	1·20	No skin.
Paraffin oil	72·05	33·36	10·40	0·11	No skin.
Corn oil	100·72	95·35	93·12	0·42	No skin; crawled.
Cottonseed oil	100·68	96·08	94·10	0·07	No skin.
Light tar oil	31·18	11·65	—	0·09	Slick crawled.
Heavy tar oil	67·21	38·27	—	0·06	No skin; crawled.
Resin oil	62·89	19·59	—	0·06	No skin; crawled.
Crude tar oil	51·83	34·32	—	0·06	No skin; crawled. very much.
Resin oil	63·64	10·12	—	0·03	No skin; crawled.
China wood oil	102·20	98·75	—	0·03	Skin.

Under the head of Remarks a statement is given as to the behaviour of the liquid. Most of it dried down to a skin. The first exception to this was raw linseed oil, and the reason was that even when painted as a film on wood it takes at least four days for it to dry. There was evidently not a sufficiently free admission of air in the oven to dry down the bulk of oil in the crucible.

Drying of Raw Linseed Oil.—The tests show that while raw, linseed oil is one of the strongest binding oils we have; it is nevertheless a very slow drying oil, and hence pure linseed oil cores would probably take longer to dry than those made from other oils.

Drying China Wood Oil.—This oil is made from the tung nut which grows in China. It partakes at once of the nature of an oil and a varnish gum, being to some extent a natural varnish. It contains its own driers, so that it dries down fairly readily. It will be noticed under the tests in the second column that China wood oil gained 2·2 per cent. in weight by oxidation when exposed to a temperature of 212° Fah. Several of the oils gained slightly, but China wood oil leads them all in this respect. It also showed the greatest percentage of weight after one hour in the core oven, and the film was strong and tough. When tested as a binding oil it gave excellent results.

Drying of Light Tar Oil.—The light tar and a number of similar oils crawled up the face of the crucible and dried down to a hard glazed film. Such oils are used as blending oils in liquid core compounds.

Drying of Boiled Linseed Oil.—The boiled linseed oil dried down to a film in the air bath, as would be expected, on account of the fact that it contains artificial driers. Formerly the term boiled oil meant linseed oil which had been boiled in open kettles exposed to the air so as partially to oxidise it, and certain mineral oxides were added to it. Such oil when used for mixing paints dried down to a film much more rapidly than raw oil. To-day practically all of the boiled oil on the market is a compound which has been heated to a certain temperature below that of the boiling point of linseed oil and had various so-called driers added to it, which chemists call catalysts. That is, they are in this case bodies having the property of taking oxygen from the air and delivering it to the oil to hasten its oxidation or drying. The boiling of linseed oil in a kettle or the making of so-called boiled oil by adding driers hastens its setting or drying by partially oxidising the material. Hence a lower ultimate bonding power would be expected from such an oil, and results seem

to show that this is true. For this reason, when considered purely from the standpoint of an efficient bond a raw oil is better than a boiled one.

Effect of a Sticky Oil on Piecework.—The author ran across an interesting condition where the pieceworkers in a core room claimed that they could not make a good output when using raw oil, since it gummed the boxes more rapidly than boiled oil. The chemist in charge stated the reason was that the raw oil contained mucilaginous "foots" which had been taken out of the boiled oil. Several oil chemists claim that in the modern process of boiling oil everything in the raw oil is to be found in the boiled oil, but that the mucilaginous material may be partially eliminated by combining it with driers.

Linseed Oil "Foots."—Practically all linseed oil is now made by the hot pressing process, and as it comes from the press contains some exceedingly fine meal, which settles to the bottom of the oil storage tanks and is known as foots. After the clear oil has been drawn off that at the bottom containing the foots is used as a core oil by many foundrymen. It has high binding power, but tends to stick to the boxes.

Comparison of Molasses and Glutrin Films.—Before leaving the subject of the tests made to determine the amount of binding power in the various materials, it may be well to refer to the films left by glutrin and molasses. The glutrin film dries down to a compact mass very much like the oils. This explains why glutrin cores do not swell in baking, but retain their size and shape, so that the baked core, if it has been properly supported during baking, can be returned to the box after drying and will fit perfectly. In the case of the film left by molasses, the liquid boils to the top of the crucible, forming a rough mass composed of bubbles. This is why molasses cores are frequently distorted during baking.

(To be continued.)

DUGALD CLERK, D.Sc.

AT the degree day of the Manchester University on Saturday last, Mr. Dugald Clerk, F.R.S., the eminent gas-engine expert, was awarded the honorary degree of Doctor of Science. Prof. Hickson, who presented the recipient, said the University of Manchester, situated in the centre of a great industrial population, was glad to recognise the important part that was played in the world of commerce by those whose scientific ingenuity had enabled them to invent improvements in machinery. The throb of the engine was, in a sense, the pulse of the community in which we lived, and they rejoiced to honour those who had contributed to make that throb a symbol of greater efficiency and power. In Mr. Dugald Clerk he had the honour of presenting a man who was not only a leading authority on the subject of combustion engines and the author of the standard work on the subject, but one who by his own inventions had placed his name in the front rank of the scientific pioneers of our time. The discovery that he made in 1881 of an alternative to the Otto cycle, followed by the construction of a 2-stroke engine, was a discovery that was made in advance of his time, for it was not until some 30 years later that the full importance of this part of his work was realised. At the present time most of the largest gas engines were working on the Clerk cycle. His scientific work had extended continuously up to the present day, and his researches on the specific heat of gases and on explosive pressure led in 1908 to his election to the Fellowship of the Royal Society. The staff and students of the Engineering Department of the Manchester University would long remember the course of special lectures Mr. Clerk gave within those walls on the theory of the combustion engine. He was a man of great inventive genius and a profound student of scientific theory, and he had demonstrated the essential connection of abstract scientific conception with the concrete practical improvements.

Explosion of a Petrol Tank.—Whilst a man employed at the North-eastern Railway Company's garage was repairing a petrol tank, on the 25th ult., an explosion occurred, and he was flung to the ground and rendered partially unconscious. The petrol had, it appears, been emptied from the tank some three hours previously, but apparently a little remained which, having probably become vaporised, exploded as soon as the blow-lamp the man was using was brought near the tank.

SOFTENING AND PURIFICATION OF WATER.

IN a recent article in the "Mechanical Engineer" reference was made to the strongly growing feeling amongst all classes of the community in favour of the more extended use, for industrial and domestic purposes alike, of water which has been submitted to an efficient softening process, and the object of the present article is to give in a brief form the leading details of the Lime-Soda process of water softening, which is now universally accepted as the most efficient and at the same time economical method of removing hardness from water, and which has the additional advantage of being also a valuable germicidal process.

Theoretically, water is a combination of oxygen and hydrogen (H_2O); practically, it is a great deal more than that. The chemist's formula stands for a kind of water which is not met with outside the laboratory, the nearest approach in nature to an absolutely pure water being rain water, but even this, as everyone knows, is contaminated with impurities, gaseous and solid.

All other naturally occurring water supplies contain varying amounts of organic and inorganic substances, which give the water a distinctive character. The impurities present in water may be either matter held in suspension or matter in solution, or both. The dissolved impurities which give water its peculiar property of hardness fall into two well-marked classes, differentiated by their behaviour towards heat or towards chemical reagents. The first class includes the carbonates of lime and magnesia, which are not soluble in water *per se*, but are taken into solution by the aid of carbonic acid gas, which the water has appropriated from the atmosphere or from the soil. When such a water is boiled the carbonic acid gas is liberated, and the carbonates, being insoluble in water alone, are precipitated. On this account the hardness due to carbonates is called temporary hardness.

On the other hand, the sulphates, chlorides, and nitrates of lime and magnesia are soluble in water alone, and some of them are more soluble in hot water than in cold. Hence boiling does not precipitate them, and the hardness which they cause is called permanent hardness. These two forms of hardness together make up the total hardness. Further, as the latter salts are not removed by the expulsion of the free carbonic acid, it is necessary to add some reagent which will precipitate them, and the cheapest and most readily available material for this purpose is sodium carbonate. But this substance will not act efficiently as long as there is any free carbonic acid in the water, as it is converted by the latter into bi-carbonate of soda, which has little, if any, action on these salts.

The first essential, therefore, in water softening is the removal of the free carbonic acid, and no process can be effectual which does not completely accomplish this.

As mentioned above, the carbonic acid can be partially expelled by boiling the water for a prolonged period, though not by merely heating it up to 212° Fah. This process entails a great waste of heat, and an expenditure of several shillings per 1,000 gallons to remove the free carbonic acid alone, and the latter can be much more satisfactorily got rid of by the use of lime at the cost, in most cases, of a fraction of a penny per 1,000 gallons. Once the carbonic acid is removed, the sodium carbonate required for the elimination of the permanent hardness is free to act and destroy the soluble salts of lime and magnesia by removing their bases and leaving the sulphate, chloride, or nitrate of sodium in their place. Thus, the removal of the permanent hardness is a conversion of these salts into their sodium equivalents, whereas in destroying the temporary hardness the carbonates are actually and entirely removed. Many textbooks on the subject state that carbonate of lime is soluble alone to the extent of three or four grains per gallon, but this is a mistake based on an experimental error of not completely expelling the free carbonic acid from the water with which the experiments were made. If carbonate of lime were soluble in water to the extent mentioned, it would be impossible to soften water below this figure, but, as a matter of fact, by carefully removing the carbonic acid, it is not only possible, but it is a thing of common commercial occurrence, to soften a water down below 1°. This, how-

ever, can only be done by a very exact adjustment of the lime required to remove the free carbonic acid.

It will be seen, therefore, that by the application of carefully calculated and measured quantities of lime and soda-ash to hard water, practically the whole of the hardness can be removed, the water being reduced to 1° and rendered ideally suitable for both industrial and dietetic purposes. A very brief consideration will make it evident that this process is not only the most effective but the most economical method of getting rid of the hardness of water, since the carbonates, which in England constitute the greater portion of the hardness, are removed by the cheapest and at the same time the most effective reagent known in water softening, viz., lime, while the sulphates, nitrates, &c., which form the relatively smaller portion of the hardness, are alone dealt with by means of soda.

On this account the lime-soda process is far cheaper to work than any process in which soda is employed exclusively. In addition, however, to the advantage conferred by the relatively small cost of this process, the employment of lime offers a further advantage by reason of the fact, which has recently been established beyond doubt, that lime, in addition to its softening action, exercises a most valuable bactericidal influence upon water treated by it. This has been referred to at length by Dr. Houston, the well-known director of water examinations to the Metropolitan Water Board, in his eighth report issued during the present year, and the results he gives go to show conclusively that by the use of a slight excess of lime the absolute sterilisation of water may be effected.

The significance of this conclusion is difficult to overestimate, and the discovery of this second great function of lime in the fitting of natural water for human use, is not only one of the most important and far-reaching of the recent developments of the science of water treatment, but when looked at in conjunction with the fact of the universal distribution of this substance over the earth's surface, the cheapness and ease with which it can be applied, and the fact that it exercises its powerful purifying and softening action on water without itself entering into solution to any appreciable extent, would seem to stamp it as Nature's own reagent for water treatment, peculiarly and pre-eminently suitable.

The softening of water by the lime-soda process is well illustrated by the following examples:—

River Water, Cheshire.

	Grains per gallon.
Silica	·22
Oxide of iron	·09
Sulphate of lime	7·04
Carbonate of lime	3·88
Carbonate of magnesia	3·32
Nitrate of sodium	·60
Chloride of sodium	4·10
	19·25
Hardness	12·00°

This water was treated with 1·20lbs. of the best fresh burnt lime and 1·40lbs. of soda ash (58 per cent. alkali) per 1,000 gallons, with the result that the hardness was reduced to 2°, the cost of the treatment being approximately ¾d. per 1,000 gallons. The softened water was free from any excess of soda, and perfectly suitable in every respect for either industrial or domestic use.

Well Water, Essex.

	Grains per gallon.
Carbonate of lime	20·29
Sulphate of lime	3·16
Sulphate of magnesia	·36
Nitrate of magnesia	2·44
Chloride of sodium	5·32
Nitrate of sodium	·80
Silica	·20
Oxide of iron, alumina, &c.	·08
	32·65
Hardness	24·55°

This water was treated with 2lbs. of the best fresh burnt lime and ·65lb. of soda ash (58 per cent. alkali) per 1,000 gallons, with the result that the hardness was reduced to 1½°, the cost of the treatment being approximately ½d. per 1,000 gallons. The softened water was free from any excess of soda.

London Water Supply.

	Grains per gallon.
Silica	·18
Oxide of iron	·12
Sulphate of lime	2·21
Carbonate of lime	17·07
Sulphate of magnesia	1·24
Nitrate of magnesia	·63
Nitrate of sodium	2·90
Chloride of sodium	3·68
	28·03
Hardness	20·15°

This water was treated with 2lbs. of the best fresh burnt lime and ·60lb. of soda ash (58 per cent. alkali) per 1,000 gallons, with the result that the hardness was reduced to 1½°, the cost of the treatment being approximately ½d. per 1,000 gallons. The softened water contained no soda, was incapable of forming scale or causing corrosion, while the treatment left its potability unimpaired.

The design of the apparatus for measuring and mixing the lime and soda with the hard water is of the utmost importance in a plant of this kind. The softener should consist of two principal portions, the mixing and measuring apparatus, and the settling tanks and filters by means of which the precipitated impurities are removed from the water. The mixing apparatus should be capable of separately measuring the water and the chemicals required to treat it, in rigidly defined quantities, and without liability to variation, as on the proper performance of this function the entire success of the process depends. It should also admit of easy and minute regulation. These conditions being fulfilled, the lime and soda process will give results far surpassing those obtainable by any other method of water treatment in both economy and effectiveness.

STEEL AND ITS HEAT TREATMENT.*

BY ROBERT R. ABBOTT.

STEEL is an alloy. In its most simple form it is composed of iron and carbide of iron. Heat treatment, defined according to modern practice, consists of alternate processes of heating and cooling conducted in such a way that the useful properties of the steel are increased in value. This treatment may increase all or part of the properties independently of each other, or it may increase some of the properties at the expense of others.

If a piece of platinum is placed in a furnace which is at a temperature of, say, 2,000° Fah. it will heat at a uniform rate until it attains the temperature of the furnace; that is to say, if a heating curve be plotted with time as the abscissa and temperature as the ordinate it will consist of a smooth curve. With a piece of steel instead of platinum this will not be so. The curve will contain one or more jogs, depending upon the relative amounts of iron and carbide of iron and to a less extent upon the presence of other elements. The above will be true upon cooling as well as upon heating. The temperatures at which these jogs occur are known as critical temperatures or critical points. A little consideration will show that the jogs are caused by some internal change taking place in the steel, either requiring or giving up energy.

Some analogous cases in other alloys or solutions will probably make this more clear. The change between water and ice occurs at 32° Fah. This point might be considered a critical point for water. At this temperature the heating and cooling curves show a jog. Liquid copper changes to solid copper at a temperature of 1,983° Fah. In both of these cases the physical properties of the substance above the change point and below it are entirely different; the specific heat, specific gravity, hardness, colour, and state of matter (liquid and solid) are

* Abstract of paper read before the Cleveland Engineering Society, April 23rd, 1912.

different. Now it might easily be conceived that a critical change could take place, accompanied by all the above changes, without the change in state of matter. Yellow phosphorus, which is inflammable and poisonous, can be changed into a red form by heating it to 432°. This red form is neither inflammable nor poisonous. Upon heating yellow sulphur to boiling and pouring it in water, it becomes a red, soft, gummy substance not unsimilar to rubber. Upon exposure to the air it gradually goes back to the yellow variety. This property of retaining an abnormal state by sudden cooling has an analogous example in steel. If metallic tin is held at a temperature considerably below freezing for a long time it changes to a grey powder. When ordinary iron is heated to 1,420° it changes into a non-magnetic variety, and at 1,650° another change takes places. These three different varieties of iron are known as alpha, beta, and gamma, and sufficiently rapid quenching from the right temperature is capable of retaining the beta and gamma form more or less perfectly at the ordinary temperatures. It is thus very apparent that while steel is an alloy composed of two constituents it can really be considered as being capable of forming three distinct series of alloys, viz., carbide of iron with alpha, beta, and gamma iron.

The critical temperatures of a substance are usually changed by the addition of another substance. Molten copper begins solidifying at a temperature of 1,983°. This temperature is lowered to 1,920° by the addition of 5 per cent. of zinc and to 1,650° by the addition of 30 per cent. of zinc, which is common brass. Consider an alloy of two components, A and B. If the addition of B to A causes a lowering of the critical temperature to A, it is reasonable to suppose that the addition of A to B will cause a lowering of its critical temperature (there are some classes of alloys in which this is not so). Under these conditions it is apparent that there must be some alloy of the series which would have a lower critical temperature than any other. In alloys in which this critical point represents a change in state this one of the series is known as the eutectic. In steel which exhibits a similar phenomenon not accompanied by a change in state it is known as the eutectoid. In our example we will consider that the eutectic ratio is 40 of A to 60 of B. Suppose we have 20 of A and 80 of B, we might consider this 20 of A to be combined with 30 of B to form a eutectic, leaving 50 of B not so associated. This is exactly what does occur, and we might consider such an alloy to be composed of a eutectic and either A or B.

The eutectic ratio for steel corresponds to a carbon content of approximately 0·90 per cent. This explains the reason for the importance of slight changes in the carbon contents for a 1 per cent. carbon steel instead of consisting of 1 per cent. carbon and 99 per cent. iron really consists of 15 per cent. carbide of iron and 85 per cent. iron. When the temperature of a piece of steel is raised above the critical temperature at which gamma iron is formed, we have an alloy formed of gamma iron and carbide of iron. The eutectoid no longer exists, but in its place is a homogeneous solution which goes by the name of martensite. This can be retained to a greater or less extent by sudden cooling or quenching, and is an important constituent of all heat-treated steels at some point in the process of their treatment.

Broadly speaking, heat treatment consists of obtaining different physical properties in the same steel by varying the relative amounts of the different series of alloys present. This may be done in several ways. Usually the steel belongs originally to the series containing the alpha iron. A definite amount of this can be changed to the gamma or martensite series or all may be changed to this series and then part brought back. Combinations of these two methods are also used.

Since the temperatures of the critical points is of extreme importance in heat treating, it is evident that we must be able to measure high temperatures with a considerable degree of accuracy. For this purpose pyrometers are employed. There are four general types of these: Thermocouple, resistance, radiation, and optical. The most widely used of these is the thermocouple type.

In general, if two dissimilar metals are placed in contact, there is created a difference in electrical potential at the other ends. This difference is a function of the temperature of the ends in contact, so that if the milli voltmeter be standardised to read in temperature degrees instead of milli-volts it can be used for temperature measurements.

The critical points are obtained in various ways. The most common and least valuable method as far as heat treating is concerned consists in finding the jog in the heating or cooling curve by means of an ordinary thermocouple and plotting the temperature against the time. This method usually fails entirely in getting the critical point in low carbon steels which are the most important from a heat-treating standpoint. The magnetic critical point can be obtained by means of a common magnet and a pyrometer more or less roughly. It is of very little value for the low-carbon steels, as this critical point is not the one used for general heat treating.

An extremely accurate method of detecting critical points in low carbon steels is as follows: A neutral body having no critical points, such as nickel, is placed in the furnace side by side with the steel. Three thermocouples are connected in series, and with two other couples is placed a very sensitive galvanometer having a full scale deflection equal to about 5°, while the third couple is connected to a regular pyrometer galvanometer or milli-voltmeter with a deflection equal to about 2,000°. This is to determine the temperature at which the critical point occurs. As the temperature of the steel rises, the temperature of the nickel rises with it, and consequently if not heated too fast they will both be at the same temperature at any given time, and the voltage generated by the couple in the nickel will neutralise that generated by the couple in the steel and as a result no current will flow. However, when a critical point in the steel is reached, its temperature will momentarily lag behind that of the nickel, with a resultant flow of current through the sensitive galvanometer. The temperature at which this occurs is then read off on the other instrument. Means are usually provided for making a photographic record of the position of the critical points. This is known as the differential pyrometer method. The most accurate method of obtaining critical points is by means of the microscope. This requires an extremely accurate pyrometer and a thorough knowledge of the theoretical constitution of steel.

We will now consider some of the effects of heat treatment. The elastic limit of a piece of steel is a measure of its value in sustaining a dead load constantly. The maximum strength is a measure of its ability to withstand a load in excess of its elastic limit. The reduction in area is a measure of its ability to withstand shocks (other things being equal), and also of its ability to bend without fracturing In common language it is considered as a measure of the "toughness" of the steel. The elongation is quite frequently used as a measure of properties similar to that given for elastic limit. This is not as accurate as the reduction in area. A measure of the steel's ability to withstand recurring shocks and strains is best obtained for practical purposes by a combination of the above physical properties considered together with the chemical composition and then by the physical condition of the steel as shown under the microscope.

The specific gravity of a piece of heat-treated steel is lower than before treatment. This is equivalent to saying that heat treatment causes an expansion in the steel. Depending upon the shape of the piece, this expansion may take place entirely in one direction and cause an apparent contraction in the other. The amount of this expansion is dependent to a great extent upon the chemical composition. By repeated heat treatment of a certain kind, steel can be caused to shrink.

The stiffness of a piece of steel cannot be increased by alloying nor by heat treatment. By this I mean that, provided the elastic limit is not exceeded, the amount of deflection for a given load cannot be decreased. However, heat treatment will raise the elastic limit so that a much greater load can be carried without causing a permanent set. Until the elastic limit is reached all steels, no matter how treated or of what nature, will deflect the same amount under the same load. However, the poorer grade steel or the unheat-treated one will reach its elastic limit first, and will then deflect much more and retain a permanent set.

When certain alloying elements are added to steel remark-

able results are produced. With the same degree of toughness, the strength can be enormously increased, and with the same degree of strength the toughness can be likewise increased. These alloy steels show up their remarkable properties to a greater extent when they are heat treated. Immense quantities of alloy steels are used in an unheat-treated condition. This alloy steel is several times as expensive as the plain steel, and yet we could get the same properties from the plain steel by the proper treatment.

If we endeavour to increase the physical properties by means of increasing the carbon contents, we find that it can be done only imperfectly and at a large decrease in the reduction in area or toughness.

The tremendous importance of heat treating all kinds of steels is recognised on all sides. It not only means a saving in money but a saving in weight, as well as a steel which will be far superior in resistance to fatigue. Steel rails are now being heat treated as well as splice bars for joining rails. No one can doubt that the future will be an age of heat-treated steels both in the plain and alloyed forms.

COMPETITION—ITS USES AND ABUSES.*

BY JOSEPH G. BUTLER.

THERE is an old adage, which has been dinned into my ears from my earliest recollection down to the present time: "Competition is the life of trade." I used to think—we all used to think—that this meant competition in selling prices and in nothing else. It was very difficult to get away from the idea that "competition is the life of trade" meant anything else but with reference to selling prices. Now, what else could it mean?

In recent years we have begun to analyse this matter of competition, and a great many of us have come to the conclusion, by analysis, that competition covers a great many more things than simply naming the lowest selling prices. Let me give you an illustration: A large steel company, not many years ago, whose board of directors found that its administrative expenses were several times as large as those of another steel company, which nevertheless was efficiently managed, instituted reforms and effected important economies, so that the administrative expense was greatly reduced, thus reducing the cost of steel products. Now, that was competition. The first company was competing with the second to see which could develop the lowest administrative expense. I know of many other instances of a similar nature, and I could multiply indefinitely instances of competition which was not competition in selling prices, but there is no need.

Now, let us examine and analyse this adage, "Competition is the life of trade." Assume, just for the sake of argument, and for that reason only, that it really means nothing but competition in selling prices, each seller trying to name the lowest figure. How will that benefit trade? First, by tending to increase the consumption, for the lower the price, other things being equal, the more will be consumed. Second, by placing the seller under the necessity of producing cheaply, for the more cheaply he can produce, the more vigorously he can compete. Admitting, however, that price competition tends to lower prices, it does not follow that it is the only means of lowering prices. We have had in the United States, and still have, many great patent monopolies, men making goods in which there was no price competition, and yet as a rule these men have striven to reduce prices in order to increase consumption, for enlightened self-interest showed them that the aggregate profits were larger with a large output and moderate profits, than with a small output and large profits per unit. As to price competition furnishing an incentive to the producer to reduce the cost of production, there may have been a time when that stimulus was greatly needed; when men would not think unless they were forced to think, but that is not the case to-day. Everywhere, men are thinking all the time, trying to reduce the costs of production. They do it in the industries which are subject to sharp competition in prices, and they do it in cases where they are not subject to sharp price competition. Take, for example, the underlying companies of the United States Steel Corporation. The competition among the officials and managers of these companies is strenuous in the matter of reducing costs, and in the matter of greater efficiency. The same is true of the independent companies, both large and small. There is much competition going on among the different steel companies to see how the number of accidents can be minimised, by improving modern safeguards. I could go on indefinitely with illustrations of this kind.

I insist, therefore, upon taking a broad view of this word "competition." In a newer and larger sense it really does constitute the life of trade, but not simply in the sense of price competition; in the sense rather of rivalry at all points—in developing new markets, in improving the quality of the goods and adapting them better to the uses for which they are intended and in reducing the cost of production and distribution.

I am reminded, however, that the subject assigned to me was "Competition, Its Uses and Abuses." Under the broad definition of competition which I have tried to develop I find that I have perhaps said enough already as to the uses. As to the possible abuses, I wish only to remind you that a wise thinker once remarked that many of our vices are really virtues carried to excess, and I can apply that here. When competition in reducing the cost of production is carried to the extent of over-working employés, or depreciating the quality of the goods made, it is a virtue carried to excess, and becomes a vice. The rivalry should be carried on at all points, in endeavouring to give the workmen the best conditions possible and in endeavouring to make the quality as high as possible.

Now, while we do have these various descriptions of competition in business, there is no doubt that competition in selling is a very important feature, and pursuing this method of analysis, I want to emphasize the fact that competing in price is only one of several means of competing in selling. One can compete in quality, in punctuality in delivery, in affording opportunity for inspection, in regularity of service, in remembering the customer's requirements from one transaction to the next, and so on.

Personal friendship counts for much in competition—often used and seldom abused. Generally speaking, the customer who has bought from a particular seller through motives of friendship is the one who is best satisfied. He had the confidence in his friend when he placed the order, and he is likely to have confidence in the goods when they are delivered. If the order had been secured through a cut in prices he would be fearful lest the quality had also been cut.

We started out with competition in general, and found by analysis that competition in selling was only one form of competition in business. Then we found that competition in prices is only one form of competition in selling. I want to proceed just one step farther, and analyse competition in prices. All price competition is not of the same nature. There is a price competition which is used only for the sake of securing a given order, because that particular order is needed. There is another form of price competition which is in a separate class and stands all by itself, viz., the old "destructive competition," which many have tried to avoid; when a seller reduces prices, not for the sake of securing a particular order, but for the definite purpose of bringing prices to so low a level that his rival cannot live and is forced out of the field. This form of destructive competition can do no possible good to society; it tends inevitably towards monopoly. "To the victor belong the spoils"; and the seller who indulges in destructive competition no doubt has clearly in mind the harvest he intends to reap in advanced prices as soon as he has destroyed his rival. As we are endeavouring to abolish war between nations, so we should strive just as earnestly to abolish this form of industrial warfare.

* Paper read at the New York meeting of the American Iron and Steel Institute, May, 1912.

INDUSTRIAL AND TRADE NOTES.

Rise in Price of Cleveland Iron.—Within the last few days Cleveland pig iron has advanced 2s. 6d. a ton, the most substantial rise that has been known for years. Cleveland No. 3 pig iron is on the high level of over 57s. a ton as compared with 46s. per ton 12 months ago. Increasing consumption, declining stocks, and higher costs of production are the principal causes of the increase.

Clyde Shipbuilding.—Clyde shipbuilding returns for June show that 29 vessels of 36,525 tons were put into the water, as compared with 29 vessels of 53,456 tons in the previous month. For the first half of 1912 the launches aggregate 146 vessels of 289,085 tons, as against 310,460 tons in the corresponding period of last year. The new orders booked by Clyde shipbuilders in June include a large floating dock for the British Government.

Arbitrator's Decision in Dispute at Cammell, Laird's, Birkenhead.—The award of Sir David Harrel, the arbitrator appointed in connection with the engineers' strike at Messrs. Cammell, Laird, and Co.'s shipbuilding yard at Birkenhead, has been made known. The men, who were out on strike for 11 weeks, demanded an advance of 2s. a week, and the firm offered a 1s. increase, but they remained out for the full amount. The award is for the 2s.

Cumberland Blastfurnacemen's Wages.—The quarterly ascertainment under the sliding scale in force in Cumberland shows that the average selling price of hematite iron warrants was 69s. 8d. per ton, compared with 64s. 1d. in the previous quarter, and with 62s. 4d. in the corresponding period last year. Blastfurnacemen's wages, which are now 37 per cent. above standard, advance by 7 per cent., and are 9¼ per cent. higher than they were at this time last year.

New Locomotives for the Great Central.—We understand that the Great Central Railway Company, anticipating developments in their traffic arising from the opening of the new docks at Immingham, have recently given the North British Locomotive Company, Ltd., Glasgow, an order for 50 goods locomotives, and Messrs. Kitson & Co., Ltd., of Airedale Foundry, Leeds, an order for 20 powerful eight-wheeled coupled bogie locomotives, designed for hauling heavy mineral train loads. These locomotives are to be equipped with a superheater arrangement recently patented by Mr. John G. Robinson, chief mechanical engineer to the Great Central Railway.

Strike of Labourers at Blackburn.—A large meeting of the Blackburn branch of the Gasworkers' and General Labourers' Union was held last week to consider the offers made by the textile and engineering firms in the town in reply to demands for increased wages. The masters offered an increase to all men receiving less than £1 of a shilling a week in textile departments and of 6d. in engineering departments. They made no proposal with regard to overtime, and refused an increase to men described as machine makers. The meeting decided that the terms were unsatisfactory, and, in accordance with notices given a week ago, the men have stopped work. About 800 strikers and about 3,000 men are affected.

Increased Cost of Shipbuilding.—Messrs. H. E. Moss & Co., of Newcastle, Liverpool, and London, in their half-yearly ship circular just issued, refer to the increase in the cost of shipbuilding that has taken place during the past two years. They state that costs of materials and wages continue to advance in all branches of shipbuilding and engineering, and are likely to still further increase. The opportunities for building cheap tonnage such as we have been accustomed to have, in their opinion, passed, and they doubt if they will ever come back again. Prices for building are fully 25 per cent. higher than two years ago, and many special steamers of large tonnage, exceptional speed, and good specifications, which were ordered some time ago by far-seeing shipowners, have recently been sold at very large profits, in some cases amounting from £20,000 to £30,000. The demand for nearly new ready tonnage and for second hand steamers was never greater, and such as are for sale command very high prices, as comparatively few are available, and those afloat are so profitably employed that it is frequently difficult to bring business about.

New Oil-engined Coasting Vessel.—The second of the fleet of 18 motor coasting vessels which are being built to the order of the Glasgow Motor Coasting Company, Ltd., has just been completed. The vessel, which is named the "Inniskea," has been built by Messrs. John Cran & Company, Leith. The other vessels of the fleet are being constructed by various shipbuilders on the Clyde and Forth. The feature of all these vessels, which range in size from 140 tons to 370 tons carrying capacity, is that steam power is entirely dispensed with. Internal-combustion engines of from 90 b.h.p. to 160 b.h.p., and of various types, have been or will be fitted into the different boats. The following are the dimensions of the "Inniskea": Length, 93ft.; breadth, 18ft. 9in.; and depth, 9ft. 6in. She has a carrying capacity of 230 tons on a draught of 8ft. 6in. The vessel is fitted with a Bolinder's internal combustion engine of 120 b.h.p., designed to give a speed of nine knots at sea. Crude Scottish petroleum is used by the engine, and sufficient oil may be stored in the large tanks fitted aft to keep the vessel running for a month without replenishing the supply. It is estimated that the "Inniskea" will carry from 70 to 80 tons more cargo than a vessel of similar dimensions fitted with an ordinary reciprocating steam engine and boilers.

Iron and Steel Exports.—The following statement, showing the value of the exports (domestic produce) of iron and steel and manufactures thereof from the United Kingdom, Germany, and the United States of America to all destinations in the years specified, was recently made in the House of Commons:

Years.	From the United Kingdom. Million Pounds.	From Germany. Million Pounds.	From the United States of America.* Million Pounds.
1890	31·1	11·3	1·8
1900	31·6	19·9	12·7
1905	32·5	25·5	13·3
1910	44·0	34·4	18·4
1911	44·8	41·3†	23·5

* Years ended 30th June. † Provisional figures.

For the purposes of the above statement, the German and United States official figures have been re-classified so as to bring them into line, as far as possible, with those for the United Kingdom. The latter gives the values of the exports of "Iron and Steel and Manufactures thereof," as shown in the official trade returns, with the addition of hollow-ware, the exports of which were not separately distinguished prior to 1904.

A Large New Bridge Over the Trent.—The Great Central Railway Company has arranged to have constructed across the River Trent at Keadby, near Gainsborough, a combined railway and highway bridge, to replace the present swing bridge, which for many years has carried the main line. The new bridge, in addition to serving railway purposes, has been designed to afford facilities for vehicular and foot passengers, and there will be an opening span of 160ft., so as not to interfere with barge traffic. In addition to the rolling lift span, which will be built from the designs and under the direction of the Scherzer Rolling Lift Bridge Company, of Chicago, there will be two fixed spans, each of 140ft., and one track girder span of 40ft., the girders of which form the tracks on which the lifting span rolls back. The lifting span, which will have a weight of 2,770 tons, will be electrically operated by motors carried on the leaf itself, and will be interlocked with the railway signals. The steel caissons upon which will be founded the masonry piers of the bridge are to be sunk by compressed air to 50ft. below low water level. The largest of these caissons will be 94ft. long and 20ft. wide. This bridge, when completed in two years' time, will rank as the largest and heaviest lifting bridge in Great Britain. The contract has been awarded to Sir William Arrol & Co., Ltd., of Glasgow, who are to carry out the whole of the work under the direction of Mr. J. B. Ball, engineer-in-chief of the Great Central Railway.

Ozonair Portable Apparatus.—We have received from Messrs. Ozonair, Ltd., 96, Victoria Street, Westminster, London, S.W., a copy of the new edition of their catalogue, No. 1, "Ozonair Apparatus for General Purposes." This catalogue contains illustrations, prices, and other particulars of Ozonair portable generators for purifying the air in rooms of from 3,000 cub. ft. to 12,000 cub. ft. capacity, for connecting to supply circuits or to portable accumulators. These apparatus are made in a variety of patterns, for standing on the table (horizontal or vertical current of ozonised air); for fixing on the wall; with medical fittings, &c. There are various designs, and the consumption varies from only 10 watts to 130 watts, so that in all cases, where intended for use on a supply circuit, they can be connected to any lampholder or plug. The makers claim that their Ozonair apparatus, as compared with other methods of producing ozone, are noiseless, and generate pure ozone free from the oxides of nitrogen. The catalogue also contains some very interesting information regarding the nature of ozone and the many public and industrial purposes to which Ozonair apparatus can be applied, such as ventilation, water and food sterilising, brewing, bleaching, deodorising, &c. That these are not hypothetical is proved by a list of important users, not only in Great Britain, but on the Continent and in other parts of the world, comprising public buildings, breweries, slaughter-houses, cold storage, waterworks, laboratories, and so on. Messrs. Ozonair, Ltd., will be pleased to send a copy of the catalogue to all those who are interested in the subject.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Engine governors. Kilburn. 8912.
Carburetting apparatus. Hopkins & Stansfield. 11375.
Production of fuel briquettes. Testrup & Rigby. 11551.
Forced feed lubricators. Livesey. 12928.
Appliance for preventing over-winding of pit cages. Thomson. 13452.
Automatic steam boiler feeding apparatus. Gravenhorst. 13468.
Hydraulic change-speed gear. Lake. 13545.
Motive-power plants. Wilkes & De Castilho. 13631.
Variable-speed and reversing gearing. Nettenstrom. 13647.
Traction engines. Fowler & Cooper. 13704.
Two-stroke internal-combustion engines. Dörwald. 13769.
Means for regulating internal-combustion engines. Gambel. 13811.
Condensers. Hall-Brown. 13848.
Valve mechanism for internal-combustion engines. Goby. 13853.
Means for operating valves from a distance. Soc. Courtaud, G. Garnier, Gil, et Cie. 13892.
Economisers or feed-water heaters. Harbinger 13923.
Manufacture of wire ropes. R. S. Newall & Son, Ltd., and Skelton. 14011.
Water motors and pumps. Smith. 14053.
Control valves. Jennings. 14115.
Gas generators. Bingham. 14232.
Fixed radial-cylindered internal-combustion engines. King. 14293.
Rolling mills. Fawell. 14346.
Heating and circulation of feed water of steam generators. Fletcher. 14468.
Operating and locking railway and tramway points. McGregor. 14525.
Method and material for coating metal with metal. Burgess. 14537.
Monorail railways. Maloney. 14900.
Tool for lifting engine valve springs. Eaves. 15402.
Devices for separating liquids from gases or vapours. Bartl. 15494.
Apparatus for signalling the operation of engine controlling gear. Lake. 15682.
Apparatus for cleaning boiler tubes. Fraissinet. 15878.
Feed-water heaters. Meijer, Pullen, & Pullen. 16040.
Steam pumps. Gage. 16045.
Spoked belt pulleys. Marston & Hough. 17104.
Change-speed and reverse mechanism. Wolseley Tool and Motor-car Company, and Rowledge. 17651.
Hoisting machinery. Bamforth & Rodgerson. 18110.
Preventing smoke in boiler furnaces. Harrison & Brown. 18376.
Axle boxes for railway wagons. Oxley & Parker. 19029.
Starting device for internal-combustion engines. McErlane. 19802.
Gas producers. Von Kerpely. 20633.
Metallurgy of zinc. Thierry. 21014.
Cranes. Pitt. 21161.
Power-transmission mechanism. Minor. 21500.
Carburetters for explosion motors. Mauvillier. 22438.
Nut locks. Howe. 23563.
Gas producers. Ragot & Pierre-Hervotte. 24461.
Ball bearings. Schutt. 24655.
Wrenches. Marks. 24749.
Boiler feed-water regulators. Cade & Knapp. 25308.
Internal-combustion motors with slide valve action. Fischer. 25475.
Chucks. Wahlstrom & Burchardi. 26413.
Vacuum gauges. Schaffer & Budenberg, Ltd. 27082.
Gas generators. Hoeller. 27547.
Liquid transmission apparatus. Barbey. 27721.
Construction of ships. Hogg & Carr. 27814.
Traction engines. Ingram. 28183.

1912.

Apparatus for indicating speed at a distance. Siemens Bros. and Co. 399.
Apparatus for discharging metallurgical furnaces. Gottlieb. 883.
Colliery tram or wagon couplings or shackles. Evans. 1317.
Apparatus for use in the manufacture of axles. Johnston. 1570.
Joining or coupling of pipes. Prockter. 1816.
Speed indicators. Bonniksen. 2052.
Steam turbines. Parkyn & Nuttall. 2094.
Apparatus for pumping lubricating oils into engine cylinders. McLaren & McLaren. 2677.
Rotary internal-combustion engines. Sanchez & Baradat. 2740.
Rotary pumps. Internationale Rotations-Maschinen Ges. 2920.
Process and apparatus for generating rich gases. Lahaussois. 3113.
Screw propellers. Kempf. 4177.
Lubricating apparatus. Watres. 4242.
Electrodes or anodes employed in the prevention of corrosion in steam boilers. Cumberland. 4251.
Railway rail joints. Boult. 5250.
Evaporating apparatus. Wiegand. 5944.
Liquid-level indicators. Allison. 6143.
Roller bearings. Taylor. 6820.
Revolving grates for gas producers. Deutsche Huttenbau Ges. 6907 and 6908.
Brakes in connection with hoisting gear. Akt.-Ges. Brown, Boveri, et Cie. 8849.
Apparatus for drawing off working steam from steam-engine cylinders for heating and other purposes. Schmidt. 8906.

ELECTRICAL, 1911.

Suspension devices for dynamos. J. Stone & Co. and Darker. 9141.
Spark plugs. Schmidt. 13524.
Regulators for dynamos. British Thomson-Houston Company, and Pollock. 13570.
Electric lamp-holders. Bey. 14303.
Terminals for ignition plugs. Longford & Clark. 16828.
Electrical igniters for internal-combustion engines. Bellamy. 17061.
Electric heating devices. British Thomson-Houston Company. 19108.
Incandescent electric lamps. British Thomson-Houston Company, and Needham. 19109.
Circuit arrangements for automatic telephone exchanges. Siemens & Halske Akt.-Ges. 19456.
Automatic sectioning means for limiting accidental interruptions of current supply in central stations. Bradenburg. 21149.
Automatic regulation of variable-speed dynamos. Prior & Prior. 21215.
Electric signalling apparatus. Hermsdorf. 22123.
Electric batteries or accumulators. May, and Electrical Power Storage Company. 22281.
Driving mechanism of portable electric generators. Record. 22655.

1912.

Electric arc winding. Strohmenger. 1274.
Arc lamps. Korting & Mathiesen Akt.-Ges. 3269.
Lightning arresters. Stoffels and Van der Sprenkel. 4885.
Means for connecting electrodes for electric furnaces. Geb. Siemens & Co. 6248.
Electric connection box with revolving contacts. Waterhouse, and Simplex Conduits, Ltd. 6961.
Arrangement for starting groups of electrical machines. Thompson. 7135.
Electric ignition apparatus for internal-combustion engines. Kettering. 7428 and 7430.
Brush holders for dynamos. Akt.-Ges. Brown, Boveri, et Cie. 7578.

METAL QUOTATIONS.

TUESDAY, JULY 2ND.

Aluminium ingot	70/- per cwt.
" wire, according to sizes, &c. ......from	102/- "
" sheets " " ...... "	120/- "
Antimony ...... £27/10/- to	£28/5/- per ton
Brass, rolled	8¼d. per lb.
" tubes (brazed)	11⅝d. "
" " (solid drawn)	9⅞d. "
" " wire	9¼d. "
Copper, Standard	£77/2/6 per ton.
Iron, Cleveland	57/3 "
" Scotch	63/3 "
Lead, English	£18/17/6 "
" Foreign (soft)	£18/12/6 "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£8/10/- per bottle
Silver	28⅛d. per oz.
Spelter	£25/17/6 per ton.
Tin, block	£208/-/- "
Tin plates	14/7½ "
Zinc sheets (Silesian)	£29/5/- "
" (Stettin; Vieille Montagne)	£29/7/6 "



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The Condition of Engineering.

It is a long time since engineers in Lancashire were so concerned as to the stability of their businesses as at present. During the last six or seven months four noted firms of engine builders and boiler makers in Lancashire have found themselves in financial difficulties. One of these is closing its doors, and another, the well-known firm of Messrs. John Musgrave & Sons, Ltd., was offered for sale, by order of the Court, on July 2nd, whilst rumour insists that other firms of note are in situations almost as difficult. It is certain that the present condition of affairs is without precedent, in recent years at least, and in view of the fact that the general trade of the country, and particularly the iron and steel trades, is enjoying a period of remarkable activity, it is clearly necessary that engine builders and boiler makers should look very seriously and carefully into their position and prospects, and be prepared to take radical steps in order to achieve once again something of the prosperity which was formerly theirs.

Misfortune naturally calls forth sympathy with the unfortunate ones, but there are various ways of showing sympathy. At the present time in business, as in politics, there is a tendency to treat every trouble as due to some cause outside the unfortunate's control, but those who feel inclined to view the engineering situation from this standpoint, and to preach resignation, would do well to remember the words a dramatist of the modern school puts into the mouth of one of his characters. It is proper to make the fullest allowances for the failings of others, but it is wise to treat one's own as evidence of a malignant but curable disease. Resignation is not a policy; it is a surrender. Nor will abuse of others help. Labour unrest is irritating and disturbing to employers, but labour unrest does not explain the present situation. On the contrary, of all the important trades few have been less directly disturbed than engineering. Nor can foreign competition be fairly blamed, for there are few British industries less subject to serious foreign competition

than that of the boiler makers and engine builders of Lancashire. It is true that a few isolated foreign engines have found their way in, but they are indeed few, and as regards boilers most of us have never even heard of a foreign boiler finding its way into a cotton mill or even an electric power station in this country.

The only safe assumption to make is that the cause of the trouble is to be found in the firms themselves—their workshops, organisation, technical ability, and directing forces. To these should be added the state of the engineering trade, which, until the latter part of last year, had remained consistently bad for some years. Bad though trade was it certainly did not justify the astonishing price-cutting which took place in the boiler trade, and, but to a less extent, in the engine trade also. It is admittedly one thing to see the folly of price-cutting, and quite a different problem to devise some means of putting a stop to it. It is almost impossible for one firm to make a stand in these circumstances, just as one trooper cannot stop a panic-stricken squadron. But a squadron composed of men who are well armed, who have confidence in themselves and in their leaders, does not get into a panic. It may be beaten, but not disgraced. And if engineering firms were on a firm foundation, if they had confidence in their own individual and collective capacities and confidence in the informal but recognised leaders of the industry they would not break away as they do.

It is clear, indeed, that the trouble is deep-rooted. Tremendous progress has been made in power engineering during the present century, but with rare exceptions that progress has left those most concerned as they were. A few firms show signs of an awakening, but the majority make very much the same products as they did 10 or 20 years ago, when the steam turbine was unimportant, the large gas engine unheard of, the Diesel oil engine to all intents and purposes non-existent, the water-tube boiler not fully developed, and the possibilities and influence of the large public electric supply station unforeseen. Other and rival firms realised the significance of the changes which were taking place, and are now in possession of the available markets and making great efforts to enlarge them by driving out the older firms. Such a state of affairs indicates that the old firms did not appreciate the progress and flux of their own industry. The majority of those responsible for the direction of these firms were too narrow in their outlook and unscientific in their training, and too conservative in their temperament to appreciate what was going on. They could repeat what their fathers did before them, and do it well, but that seemed to be the limit alike of ambition and capacity. Their shops, too, were, and for the most part still are, badly equipped, and but ill-fitted to carry on a winning battle with younger rivals.

Engineering of to-day is not merely the engineering of 20 years ago grown bigger. It is more than that. It requires all the old qualities of mechanical skill and honest workmanship, and many more besides. The margin between success and failure is less than it was, and every item down to the least must be studied, so that it is produced in the most economical way, or, if necessary, ruthlessly given up in favour of something else. Skill, whether of the hands or the brain, must be more intense. It must probe deeper, and separate the wheat from the chaff—in methods and products particularly—more thoroughly than before. The outlook must also be greatly widened, and for this nothing is so good as a wide and thorough scientific training. The higher a man's position the wider should his outlook become. The steam engine builder can no longer afford to be content that he knows his own engine from A to Z. He must know rival machines, too, so that he knows what to defend and what is not capable of defence. He must be able to estimate the possibilities of new ideas, and to estimate the trend of progress. He may not make oil engines, but he must know what they can do, and what it costs them to do it. He must estimate what future progress the oil engine will make, and what its effect on him will be. He should travel occasionally, for there is nothing like seeing what our customers and rivals are doing, and getting into personal communication with those who have a different outlook from our own, for stimulating mental activity and bracing up initiative in a man of the right material.

What is wrong with Lancashire engineering is principally the quality of its higher personnel. There are exceptions, but in the bulk this is not equal to the work demanded of it. In straightforward, old-fashioned engineering ability it is excellent, but in technical knowledge and scientific outlook it is poor: in commercial capacity it has shown itself lacking in the essential qualities of foresight and courage, and in its knowledge of the rest of the world it comes very close to being provincial.

Pay-as-you-enter Cars.

SOME discussion is taking place in this country over "pay-as-you-enter cars" for tramways. These have now been in use several years in America, and have achieved a considerable degree of success, but here they seem unable to gain a footing. A "pay-as-you-enter car" has a large rear platform, divided by a rail into inlet and outlet sections. Before entering the car proper the passenger pays his fare, and if he requires change has to stand on the platform until the others have passed into the car, for the guard, or conductor, does not leave the platform. It is claimed that this reduces the length of the stoppages and the number of accidents due to the car being in motion when passengers are boarding or leaving the car. It should also be noted that the American cars have no upper deck, so that the task of the guard is simplified. Finally, with rare exceptions, the fare is a uniform one, and independent of the length of ride or the destination. English practice is to charge according to distance, and this, together with the presence of an upper deck, makes the application of the "pay-as-you-enter" system more difficult in this country than in America. A larger waiting platform would be required, and this would deduct seriously from the car accommodation. In some American and Canadian towns, notably Montreal, it is noteworthy that the "pay-as-you-enter cars" are being made very large, so as to reduce the percentage of semi-useless space taken up by the rear platform. The upper deck presents a problem which is probably not insoluble in a practical way. In America they have no upper deck, and smoking is not allowed on the cars. Would Englishmen consent not to smoke on tramcars? It is doubtful, for to-day the tramcar is an Englishman's castle.

Trials of a New Destroyer.—H.M.S. "Firedrake," one of the three special destroyers ordered by the Admiralty last year from Messrs. Yarrow & Co., of Glasgow, recently had a successful official full speed trial on the Skermorlie mile on the Firth of Clyde. During a continuous run of eight hours the vessel attained a mean speed of 33·17 knots, thus exceeding the contract speed of 32 knots by 1·17 knots. The vessel is 255ft. long by 25ft. 7in. beam, and is propelled by Parsons turbines driving two shafts, steam being supplied by three Yarrow water-tube boilers fitted with the firm's latest feed heating devices.

DESIGN, CONSTRUCTION, AND INSPECTION OF LOCOMOTIVE BOILERS.*

The report on inspection of locomotive boilers was presented to the members at the last convention. Relative to design and construction a circular of enquiry was sent to all the members of the association in regard to their experience and recommendations concerning construction of locomotive boilers. Replies were received from 21 members, representing a total of 22,900 locomotives, which is about one-third of the locomotives represented by the membership of the association.

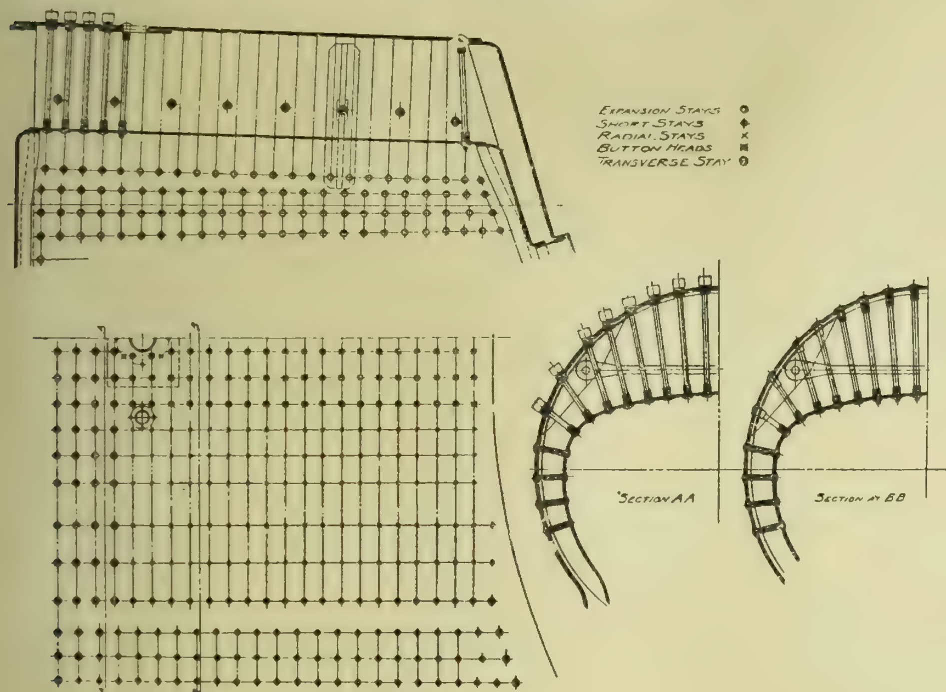


Fig. 1

Type of Boiler.—In no case is a special type of boiler used for any special service. In one instance Belpaire boilers are used of crown bar construction for road engines entirely on account of the greater ease in maintaining stay bolts. In another they use the Belpaire boiler as well as the radial stay boiler, and their experience with the Belpaire is that it reduces the number of stay bolt breakages, which has been proven by record. From the experience gained with Belpaire boilers a system of cross-bracing was developed as shown in Fig. 1, which has practically all the advantages of the Belpaire staying, and in addition it reduces the dead weight and is cheaper to construct. Crown-bar construction is not used to any extent on wide firebox boilers, but a few roads use the crown-bar construction on narrow-type fireboxes. On the crown-bar type of boiler it is found to be a hard matter to keep the crown bars free from mud, but in renewing fireboxes on this class of engines beneficial results have been obtained by raising the crown bars and inserting washers 1½in. to 2in. higher. The committee was unable to get any data in regard to merits of Belpaire boiler compared with the radial stay boiler, as far as maintenance and boiler performance is concerned.

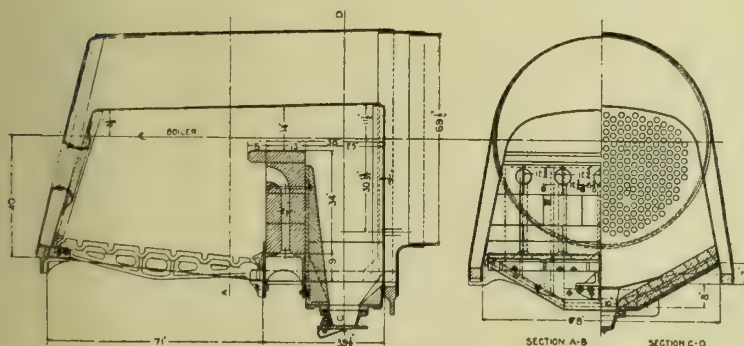


Fig. 2.

From the replies received from the different members it is the concensus of opinion that the radial stay type of boiler is preferred, as it is easy to construct, giving more free circulation of water, less deposit of sediment on the crown sheet and easier to wash out; also the dead weight is kept down considerably.

Combustion Chambers. — The combustion chamber is favoured by only five members. One, who uses the combustion chamber illustrated in Fig. 2, advises that it shows a great economy in fuel, a decrease in the amount of smoke and cinders, and increased mileage. No information was given in regard to maintenance. Another member advises that the reason they favour the combustion chamber in certain types of boilers, such as the Mallet, is that it keeps the tubes a reasonable length and increases the heating surface of firebox. No information was given as to the fuel economy derived from these combustion chambers, but a saving in maintenance and an improvement in performance is reported. Another member reports being in favour of combustion chambers, but does not have them on all engines. This member was from an anthracite road, and the particular claim was they thought they got better combustion and also derived a good deal of benefit in the way of protection of flues, particularly so, the boxes being extremely shallow below the flue sheet. Another member advises that they have had five passenger engines with combustion chambers as shown in Fig. 3, but considerable difficulty was experienced in keeping the seams tight, and on account of this fact combustion chambers were removed when applying new fireboxes. This was the first development of the combustion chamber which has been materially improved since that time.

On another road they have had all combustion chambers removed on account of costing too much to maintain. The advantages claimed by the use of combustion chambers are that it keeps the tubes within a reasonable length, protects the flue beads, increases the firebox heating surface, and gives better combustion. The committee feels that a combustion chamber is desirable on boilers with extra long flues, such as the Mallets and the Mikados, but are not prepared to recommend any particular design.

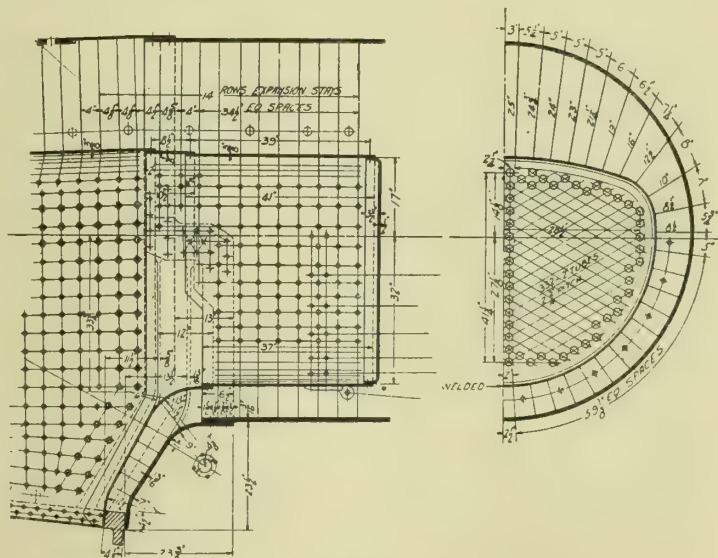


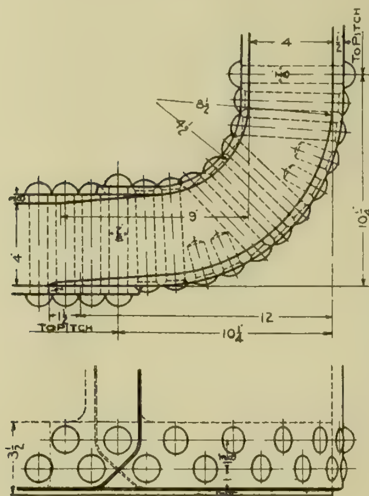
Fig. 3.

Firebox.—Continuous crown and side sheets are favoured by all members except one. Therefore, the committee recom-

* Abstract of a committee report presented at the annual convention of the American Railway Master Mechanics' Association.

mends the use of continuous crown and side sheet for new construction or with renewal of firebox.

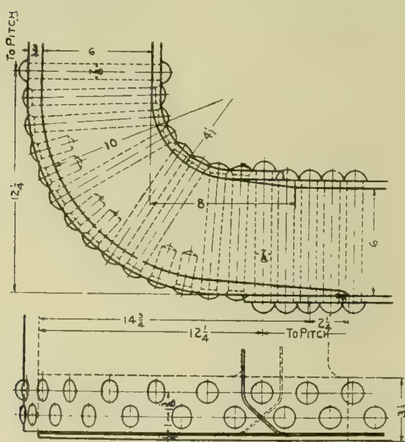
Mud-ring Corners.—Type of mud-ring corners which have been giving good service are shown in Figs. 4, 5, and 6. One member advises that they use a cast-iron plate held in place with a ¾in. bolt and a cast-steel clamp, leakage being prevented by a composition joint. The committee recommends mud-ring corners of large radius, as shown in the several illustrations, and that the flanges of the tube and door sheet be carried back far enough to get at least three straight rivets through the ring. Scarf the inside sheets down to be properly fitted to the mud ring by heating same. If the scarfing and the fitting of these sheets is given proper attention it will overcome leaky mud-ring corners with which some of the members are now experiencing considerable difficulty.


Fig. 4.

Throat Sheet.—In general, the distance from the top of the grate to the bottom of the lowest boiler tube on wide firebox engines is a minimum of 14in. and a maximum of 26in., average about 22in. Narrow fireboxes have a minimum of 13in. and a maximum of 28½in., average about 20in. In one case where hard coal is used, a distance of 8½in. minimum and 12in. maximum prevails. This height is limited to the design of the locomotive.

The committee recommends as deep a throat sheet as the design of the locomotive will permit. On consolidation engines the depth of the throat sheet is limited, due to the frame passing under the firebox and on account of the rear driving wheel, which is located under firebox. On Atlantic, Mikado, Mallet, and Pacific type engines, a deeper throat sheet can be obtained, as it is not necessary for the frames to pass under the firebox. The committee also suggests the design of throat sheet as shown in Fig. 7 on boilers with sloping mud ring to allow for more uniform spacing of stay bolts and location of arch tubes and simplifies the flanging of the throat sheet and flue sheet.

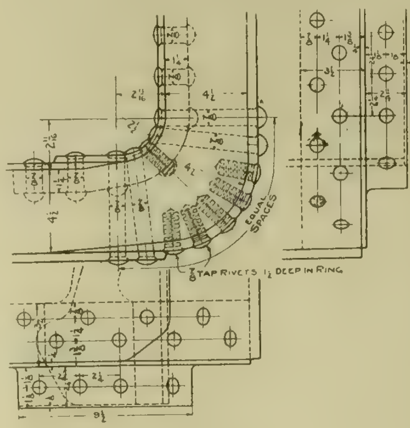
In regard to thinning out of flue and door sheets, also the use of countersunk rivets where these sheets are joined to the side sheets, the different methods employed will be found indicated in Fig. 8. About 50 per cent. of the members thin out these sheets and apply countersunk rivets. It is generally acknowledged that the thinning of the sheets and the countersinking of rivets is necessary on oil burning locomotives. The general practice seems to be to countersink these rivets about half-way up the side sheet. No data were given in regard to which practice is the best from a maintenance standpoint.


Fig. 5.

Spacing of Rivets in Firebox Seams. — The committee suggests ¾in. rivets spaced 2in. apart, as this is used in the majority of cases.

Design of Fire-door Hole.—Fig. 9 shows various designs of fire-door holes used by different members. Three roads use style No. 2, which is the O'Connor type of fire door. One of the members reports that they have 1,200 locomotives equipped with the O'Connor type of fire door for a number of years. On boilers equipped with this type of fire-door flange they have had several cases where the door sheets have remained in perfect condition, although two sets of side sheets and a second back-flue sheet had been applied and cracked badly. In every instance the door hole remained in practically perfect condition when the rest of the firebox was cracked to the point of renewal. Boilers equipped with this type of fire-door hole give larger water space, fewer stay bolts about the door seam, seem to give freedom for expansion and contraction and also largely prevent mud and scale collecting at this point.

Arch Tubes.—Fifteen roads reporting use 5in. tubes, one uses 2in. tubes and one uses 2¼in. tubes. Five do not use arch tubes at all. One supports brick arches with studs fastened into the side sheet. Thickness of tubes used: ·15in., ·165in., ·18in., ·203in., ·25in. Eight use thickness of ·18in. Eleven use seamless steel, one uses charcoal iron, thickness of tube not given.

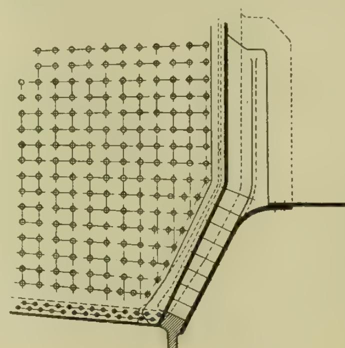

Fig. 6.

Plugs or Plates for Covering Arch Tube Holes in Throat Sheet and Back Head.—Twelve roads use brass plugs, one uses extra large size brass plugs for covering the holes; these plugs are drilled for 2¼in. plug so as to avoid removing the large brass plugs when washing the tubes. Three use plates with ball joints, claiming greater ease in removing and applying in close quarters.

Method of Setting Arch Tubes.—The setting of arch tubes varies. Six roads advise that they use copper ferrules in setting arch tubes. Three roads set the arch tubes without ferrules. Three set the tubes with a roller expander and a sectional expander to be used in the ordinary manner to set out the tube, as shown in Fig. 10. Tubes are then beaded over with a bootleg tool, except by one member who bells out the tube on the water side to prevent the tube from pulling out of the sheet. This member does not use any ferrules. The other two members do use copper ferrules. Fig. 11 shows arch tube setting as used by another road.

The committee was unable to get any information in regard to which type of flue setting gives the best service, therefore did not make a recommendation as to which type should be recommended as standard practice.

Radius of Flange in Back Tube Sheet.—In regard to the radius in the back tube sheet where it connects to the crown sheets, recommendations were made for radii from ½in. up to 2in. Some roads have had trouble with cracked sheets and leaky seams with large radius; others have trouble with the small radius. One is now experimenting with a 4in. radius and it seems to give good satisfaction, but it has not been in use a sufficient length of time to give a complete report. Two roads increased the radius from ⅞in. to 2in. and had considerable trouble with flue sheet working up and the flanges cracking. Two-inch radius has been discarded and they are now using ⅞in., which improves the condition but does not eliminate the difficulty entirely.


Fig. 7.

Distance from Inside of Flange of Back Flue Sheet to Edge of Flue Holes.—The committee recommends that a distance from the inside of the back flue sheet to the edge of the nearest flue hole to be ample to prevent the flue sheet cracking through the flange. This distance will vary, depending on the radius of the flange of the tube sheet. Tube sheets with ⅞in. radius, this distance should be at least 2in. at the top, ⅞in. on the side. Sheets with 2in. radius, the distance should be at least 2½in. at the top.

Throat Sheet Brace.—The design of brace for this location

should be such as to avoid any mud pockets and so as to allow for proper circulation of water.

Method of Supporting Grate Side Frames.—The committee recommends the grate side frames to be supported from studs in the mud ring or brackets fastened to the under side of the mud ring, the latter forming a pocket for the grate side frame to fit into.

Sloping Back Heads.—Sloping back heads are used by practically all roads. The slope varies from 8° to 20°, making an average slope of 12°. Sloping of back heads gives additional room in the cab, reduces the weight of the boiler, and gives a maximum length of firebox, and still remains within a reasonable limit for hand firing.

FIG. 8.

Stay Bolts.—Uniform spacing of all stay bolts in all parts of the firebox is recommended by your committee. The majority of the roads reported the use of button-head crown stays for the six to nine centre rows of the crown sheet the entire length; two members use hammered heads for the first four or five rows from the flue sheet. The different forms of button heads are shown by Fig. 12, on which you will note that there are nine different designs shown. The road that uses style No. 4 advises that they are having some difficulty keeping the button heads tight. The committee favours the use of button-heads on as many rows as the design of firebox will permit, but recommends for the consideration of members the practice of using hammered heads on the first four or five rows back from flue sheet.

Sling Stays.—Figs. 13 and 14 show the various types of sling stays in use by the different roads, and no difficulty with any of these types has been reported. Three roads use a special flexible stay bolt on all new equipment, as shown by Fig. 15, and this type of sling is also favoured, but not used, by another road. Sling stays are used to the extent of two, three, and four rows back from the tube sheet on boiler with combustion chamber.

Flexible Stay Bolts.—All roads except one use flexible stay bolts. Most of the roads apply these in the breakage zone. Five are making full installation of flexible stay bolts on boilers with wide fireboxes. One has the following report to make:—

"In February, 1907, engine received new firebox with full installation of flexible stay bolts, with the exception of four bolts under the auxiliary dome and four under steam turret; also eight bolts which go on top of same at back head. February, 1908, engine received general repairs and firebox was in good condition. All caps were removed from flexible stay bolts, and they were found to be O.K. April, 1909, it was found necessary to patch the top of the back tube sheet on account of sheet cracking from the hole around the flange; this was done in the engine-house. October, 1909, engine was given general repairs, and by this time the top of back tube sheet had given out in two more places, but as the sheet was in good condition otherwise it was patched. Three of the mud-ring corners also had to have small patches applied. After rattling scale from firebox sheets with large hammer, it was found that 40 of the flexible sleeves had cracked outside of the sheet, and on being taken out they were found to be crystallised, but no broken bolts were found. In 1911 engine was again in the shop for general repairs, and had all caps removed from flexible stay bolts and bolts found to be O.K. A patch was applied on top flange of flue sheet, half side sheet seam in firebox in good condition. When engine is shopped again it will be necessary to renew back flue sheet on account of same being patched. This engine has made 319,567 miles to November, 1911, and has lost no time due to broken stay bolts."

FIG. 9.

FIG. 10. FIG. 11.

One road has equipped some fireboxes with full installation of flexible stay bolts, but can see no advantage in doing this. In their opinion the flexible stay bolts are only advantageous when applied in the breakage zone, and they have discontinued making full installation and are only applying them in the breakage zone. However, a full installation of flexible stay bolts in the throat sheet is being used by quite a few roads with good results. Three advise that they allow a certain amount of slack when applying flexible stay bolts.

FIG. 12.

It is the belief that an application of this kind will decrease the number of broken stay bolts and allow for a greater expansion and contraction, which prevents the cracking of firebox sheets and increases the life of firebox correspondingly. The committee believes that this is a subject worthy of further consideration, and would suggest that some more of the members carry on a further investigation and make a report at some future date.

(*To be continued.*)

PRESSURE REGULATORS.*

BY S. J. WATSON.

In discussing the question of pressure regulators, it may be as well to eliminate any reference to automatic regulation which may be incorporated in the design of generating machinery. A compound winding may be termed an automatic regulator, and has been found quite suitable for special cases, but impracticable in its application for general supply purposes. The following remarks will, therefore, have reference to regulators which may be provided as a separate piece of apparatus to the machine or machines which are to be regulated. It may be noted, in passing, that close regulation on a generator, however provided, has a certain market price. Such being the case, it appears not unlikely that, as automatic regulating devices become still further improved and adopted as standard practice, designers may be allowed to attach less importance to regulation, and by so doing, improve the design in other

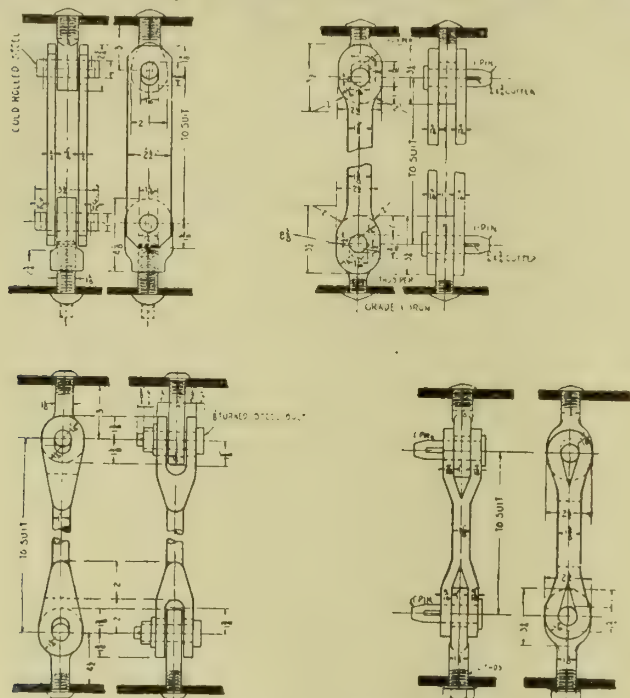


Fig. 13. (See page 29.)

directions, and at the same time effect an economy in materials and in cost.

Automatic regulators have been designed principally with the object of maintaining a constant pressure on the bus-bars at the generating station or sub-station, or even to produce a compounding effect so that the bus-bar pressure may be automatically varied to suit the load. They may also be used to maintain a constant speed on direct-current motors, which have to deal with large and frequent fluctuations of load. There exists, however, a much wider field for the application of such appliances. For instance, it is usual to connect up all feeders to a common bus-bar, but feeders are usually of different length, and adjustment of the pressure on each individual feeder may be necessary, owing to variations in the locality of the load, or to changes in the power-factor, during different periods of the 24 hours. The ideal place for the regulator would be the consumer's premises, or even on each large consuming device connected to the system, as, however constant the pressure may be maintained at the bus-bars, or at the feeder points, a certain amount of disturbance to the pressure will occur on the distributing system, through the switching on and off of large individual appliances. It is, perhaps, well to bear in mind the fact that, although voltage regulation is of the greatest importance in its relation to a direct-current supply, both for lighting and power, and also for alternating-current lighting, the development during the past 10 years of alternating-current motors for power purposes necessitates a constant motor speed for many industries, and this can only be obtained by maintaining a constant speed on the prime movers. Where the fluctuations of load are large, it may be necessary to apply the principle of the pressure regulator to the governor of the engine or turbine, so as to ensure not only a constant voltage for lighting, but also an absolutely constant frequency for power. Probably the best regulator for a direct-current supply system is a storage battery of large capacity, with an automatic booster or regulating switch controlled by the bus-bar pressure. In addition to acting as a regulator, the battery would be found exceedingly useful at the time of a breakdown or other emergency.

* Abstract of paper read before the Incorporated Municipal Electrical Association.

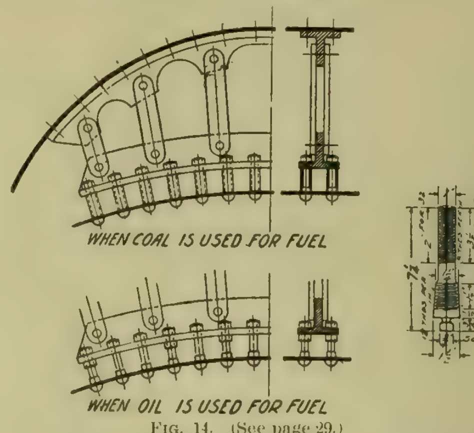


Fig. 14. (See page 29.)

The principal requirement of an automatic regulating device is, of course, that it should be, at all times, and under all conditions, completely automatic in its action. Unfortunately, few automatic devices are free from trouble in this direction. The majority of the instruments used for the purpose of controlling the pressure of supply consist either of a movable iron core inserted in a shunt coil, or of a movable shunt coil which can rotate between the poles of a permanent magnet the shunt coils in both cases being excited from the bus-bars. If the bus-bar pressure falls, the movement of the core or the shunt coil is in one direction, and if the bus-bar pressure rises, the movement is in the other direction. With ordinary changes of pressure the movement produced, and the power exerted, is quite small; it is, therefore, necessary to magnify the movement or to use relays, in order to obtain a sufficient range of regulation, and the mechanical power required to operate an auxiliary regulating device.

By means of the auxiliary device, which may consist of a small motor or solenoids, regulation is obtained by: (1) Moving the switch which varies the resistance in circuit with the field winding of the generator; (2) varying the field of a small, separate, exciter supplying the field of the generator; or (3) diverting more or less of the field current of the generator. When a number of generators are run in parallel a regulator may be used controlling them all, in which case any variation in load is distributed equally over all the plant, or with one generator only, which will then deal with the fluctuations and allow the other plant to run at constant load. Regulators are usually provided with hand adjustment to enable the bus-bar pressure to be varied, when necessary, to suit the load conditions. Quickness of operation and closeness of control must always be special features in automatic regulating devices, particularly when a mixed system is supplied from a common bus-bar; but for lighting purposes only extreme sensitiveness in the instrument is not so essential. A variation in pressure of 1½ per cent. up or down over a period, say, of 20 seconds, would in such a case give almost as good results in practice as absolutely instantaneous operation, but where lighting is supplied for general purposes from a power main dealing with a large and fluctuating load, or from a railway supply, a similar regulator would be almost useless.

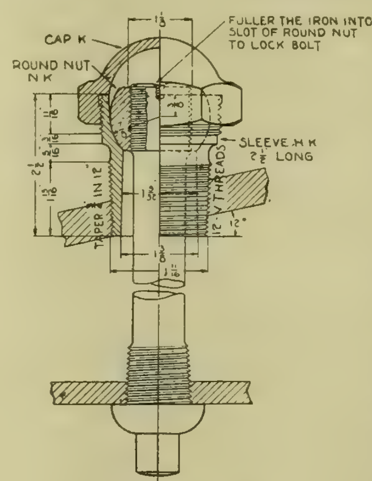


Fig. 15. (See page 29.)

It is difficult to express the value between a system where the pressure regulation is good and where it is bad, but that it must have a very real value from the user's point of view, is undoubted. By installing automatic pressure regulators, the supply undertaking not only improves the service, but the amount of attention required by the switchboard operator is appreciably reduced.

ANNUAL REPORT OF H.M. ELECTRICAL INSPECTOR OF FACTORIES.

(*Concluded from page 15*).

During the year a considerable amount of work has been done by the district staff in enforcing the requirements of the regulations as regards the more obvious contraventions, such as exposed conductors, switches, fuses, &c., and dangerous hand lamps. Several inspectors who have had technical experience before joining the Department, Mr. T. K. Evans in Scotland, Mr. C. A. Taylor in North London, and Mr. Topham in South London in particular, have done useful work on a wider basis. My own inspections during the year included generating stations and sub-stations of electric power supply companies, public supply undertaking, railways and tramways, and other industries and works of various kinds where electrical energy is used, including electrical manufacturing works, electro-chemical works, docks, engineering works, mills, laundries, &c. Many of the visits were made at the request of the occupiers or their engineers in charge of the electrical work, others in reference to accidents, and some as the result of complaints. For the most part, the dangerous conditions which I found and which contravened the requirements of the regulations, were similar to those I have described in detail in former reports. Although it is evident that generally much greater attention is given to questions of safety, no doubt as a result of the establishment of the regulations, there are numerous instances where occupiers or their responsible engineers do not take the necessary steps until the various matters are pointed out to them in detail. I again found examples of new work which were not in compliance with the requirements. The electrical contractors are often responsible for this, either in not taking the trouble to consider the regulations or, as is evident in some cases, for the sake of cheapness. Even where the occupier specifies that the work is to be carried out in accordance with Home Office regulations, it is not always done. In one of these cases, where a new factory had been fitted up for light and power, a number of points were not attended to. I met the contractor's engineer on the works, and, as he admitted that he was fully cognisant of the requirements, I enquired why he had not carried them out. The answer was quite candid, and to the effect that he deliberately took the risk, not expecting that I should pay a visit to the works before he had finished with it. A similar case was reported by Mr. Topham, where a new alternating-current installation had been provided with a number of hand lamps of an old and dangerous type. The contractors assured the occupiers that there was nothing amiss, and it was not until the latter were served with a notice that they would be prosecuted on the first occasion that the lamps were found to be in use that the contractors could be induced to change them.

Dangerous fuses continue to be found even in new work. This is probably partly due to stocks of undesirable patterns being still on the hands of dealers, although, judging by advertisements which appear in the trade papers, it would seem that they are still being manufactured. One manufacturer who has now introduced a satisfactory line of new patterns informed me that he still makes the old ones, as they are in considerable demand for export, and he, of course, has no control as to their ultimate use in this country on factory premises. I have described the usual defects in fuses in former reports. A common fault is that they cannot be handled for purposes of renewal without danger of shock through touching live metal. Thus I found grip type fuses having a porcelain grip only about 3in. in length, with exposed live metal end contacts in use on 500-volt and 440-volt alternating-current systems unprotected by switches, and in earthed metal cabinets, and some over metal floors, and others out of doors over wet ground. It is impossible to handle such fusses without risk of dangerous shock. Similar fuses of the cartridge type are also often found under like dangerous conditions. Another common type of fuse carrier for small fuses has the fuse wire lying in a groove on the front of the porcelain bridge, so that apart from the risk of shock there is danger to the person renewing the fuse wire, when replacing the carrier on the fuse board, of getting his hand burned should the fuse blow, as it often does, just at that moment by reason of the fault on the circuit which caused it to go in the first instance not having been rectified. In cases where fuses are protected by switches, they are sometimes placed in a dangerous position. Thus, open-ended tubular type fuses, often for large currents, are placed on switchboards immediately above or below the switch without any intervening guard, so that if they should blow at the moment of switching on, the switchman is liable to get his hand severely burned. I found a number of instances of such an arrangement with fuses up to 1,500 amperes capacity. Such fuses for circuits of large current are liable to be dangerous in any event and ought not to be used unless specially guarded. Reliable circuit-breakers are now obtainable at prices which will allow of their adoption on circuits of comparatively small current and are often to be preferred to fuses.

In engineering shops I found unprotected main distributing switchboards for alternating current power circuits not in an area set apart and with lathes and drilling machines, &c., within a few feet, to the imminent danger of the men working at the machines.

Manufacturers of electric irons do not yet appear to have realised that these articles when used on factory premises come under the Regulations, and that in many places they are liable to be used under conditions which necessitate their being earthed, no provision being made for the attachment of an earth wire. In one laundry I found ten irons in use on a 200-volt alternating supply. The floor was of brick, non-insulating, and the girls complained that they received shocks from the irons and had to be very careful to handle them with a cloth, so as not to touch the metal parts. The flexible wires, which were all twisted up and the insulation damaged, were connected by means of adapters to lampholders and there was no switch in the room, the only switch being the main supply switch in an adjoining passage and placed quite out of reach. The conditions were such as might readily lead to a fatal accident. The proprietor raised no objection to discontinuing the use of these irons as he had decided to do so in any case within a few days, owing to the fact that they did not get hot enough for the work. While electricity supply authorities are using every endeavour to get their consumers to adopt electrical methods of working, it seems a pity that in such a case as this there should not be supervision to ensure that the consumer shall get an article suitable to his needs and also that it shall be properly and safely installed. The trouble referred to above, of the flexible wires becoming twisted up into knots and damaged by repeated pulling out, is a common one where electric irons are used. I found in another case that it had been overcome by the use of flexible metallic sheathing. This was rigidly fixed at one end at a point about 5ft. above the table, and at the other to the iron. While this gave all necessary flexibility for the movement of the iron, it was found that the latter could not be twisted round more than a couple of turns without causing such a strain on the girl's wrist as to cause her to untwist it. If twisted up for more than a couple of turns, it would of itself untwist, turning the iron round when the hand was removed.

In a number of works old-fashioned and dangerous types of hand lamps were still in use, and sometimes incandescent lamps were used merely in lamp-holders as portable lamps, the lamp-holders not being earthed. One of the fatal accidents referred to elsewhere was attributable to this arrangement, which is of course just as dangerous as the use of hand lamps having a metal guard in contact with the lamp-holder. Safety hand lamps which do not require earthing are now made by a considerable number of manufacturers. Unfortunately hand lamps and other fittings are sometimes advertised and sold as of "Home Office pattern" without any justification. In one such case a well-known firm put on the market as of "Home Office pattern" a hand lamp which outwardly looked to be entirely satisfactory, and it was not until I took one to pieces that I found that the metal guard was in actual metallic connection with the lamp-holder. It was necessary to inform the firm that the occupier of any factory where these hand lamps might be found in use would be liable to prosecution. The firm took steps to recall from their agents all the defective lamps, but unfortunately it is impossible to trace those actually sold. In this case the fault

does not appear to have been in any way intentional, or due to a desire to produce a cheap article, but merely to ignorance on the part of the designer who seems to have copied certain features of other lamps, but rendered the result abortive by the method adopted for fixing the several parts together.

In many works, particularly engineering works and shipyards, the importance of adequately earthing frames and covers of electrical apparatus is not always appreciated. A fatal accident due to this neglect is referred to elsewhere.

In an electro-chemical works I found bare conductors carrying several thousands of amperes having gas pipes run alongside, and with swivel gas brackets in some cases so arranged that they could be turned so as to touch the conductors.

In important electricity supply and traction undertakings there is often neglect of elementary precautions, and the presumably competent persons employed do not always appear to realise the risks they often unnecessarily take. Thus, in a railway sub-station I found an attendant eating his supper while sitting on the bed-plate of a motor generator, with a bare terminal block at 600 volts above earth only two or three inches behind his head.

There are still to be found in use numerous examples of switches of a dangerous type, which I have so often described before, in which the handle cannot be grasped without danger of touching live metal. On a public supply station switchboard I found double-pole switches with live nuts on the handle side of the cross-bar less than three inches apart, with the switch handle between, there being 500 volts difference of pressure between the nuts.

In certain railway sub-stations I found the direct current switchboards, 600 volts above earth, with the back passageways having no flooring over the trench, but instead a narrow iron grid on which a person might readily trip up, in which event he would be bound to catch at the live conductors. I found also in public supply and railway electrical stations, unprotected conductors at high or extra high pressure, switchboards with switches and other bare conductors, unprotected, both on the front and back. In one case a boy of 17 was employed to clean the floor behind such a switchboard at the immiment risk of his life.

In some cases of public supply, where extra high tension sub-stations are placed on consumers' premises, it had been considered by the supply authority that sufficient precaution had been taken by locking up the sub-station as against the consumer, regardless of the fact that the sub-station is a factory on its own account and that precautions are needed in regard to the supply authority's own employés.

In the case of important new stations, the engineers responsible for the design do not always give sufficient attention to the practical side of the subsequent running of the station. Two examples of such want of foresight came to my notice during the year. One was a new station for supplying light and power in a large iron and steel works. High pressure 3-phase current is generated and is required night and day, including Sundays. The switchboard, although divided into sections, was not arranged for screening off live parts from dead parts in case of work having to be done. It was therefore impossible to undertake any cleaning, repairs, or overhaul of the apparatus in safety without shutting down the station. The other station was also high pressure 3-phase for the supply of electrical energy over an extensive area through sub-stations. Here, again, the switchboard was badly designed. All the necessary isolating switches were there, but were wrongly connected and arranged. The oil switches for both generators and feeders were connected directly to the bus-bars, the isolating switches being between the oil switches and the generators and feeders. By this means, although it was possible to isolate any generator or feeder, it was impossible to isolate any of the oil switches. Should an oil switch require overhauling, and in every well-managed station such oil switches would be examined and overhauled periodically whether they had given any trouble or not, the work could only be undertaken by shutting down the whole supply. In this case a firm of consulting engineers was responsible for the arrangement.

Towards the end of the year a disastrous dust explosion occurred in an oil-cake mill whereby a number of persons lost their lives. Electricity was used on the premises for lighting and for energising the magnets of the separators. As the electrical installation was to some extent under suspicion as having fired the dust, I made a careful examination on the part of the premises affected, particularly in a certain room in the basement in which it was agreed that the explosion originated. Blown fuses were found in this room and also a broken magnet wire with fused ends. Experiments conducted with dust taken from the works showed that when formed into a dense cloud it could be fired by the melting of even a small fuse on a lighting circuit or by the spark produced by the breaking of a wire carrying the current for one of the magnets. There was, however, no evidence to show that either of these phenomena was the cause rather than the result of the explosion, which the experiments also showed could equally well have been produced by the striking of a match. A dust-cloud was supposed to have been raised by the breaking of a belt, and it is readily conceivable that in the darkness produced by the cloud in an already dimly-lighted basement, a man might have thoughtlessly struck a match. Whatever the cause of the ignition may have been, the experiments, which were carried out by means of special apparatus devised by Mr. McNair, showed clearly that in premises where such dust-clouds are liable to be formed, special precautions should be taken in regard to any electrical installation to prevent the possibility of any sparking or arcing where it could ignite dust.

Although a report on my work must necessarily deal mainly with the unsatisfactory and dangerous features which come under my notice, and with which I have to deal, there is on the other hand an increasing number of examples of excellent work in both electrical stations and factories. The general standard is much better than it was a few years ago. Whilst it is true that some manufacturers of electrical apparatus continue to produce old patterns with well-known faults, no doubt because they are cheaply made, and there being apparently always a market for things which will just do the work for a short time, there are others who have devoted much time and skill, and no doubt not a little money, in perfecting different pieces of apparatus. The Electrical Exhibition held in London in the autumn afforded opportunity for noting progress in different directions. A number of firms showed apparatus which they had specially designed in view of the requirements of the Regulations. These included fuseboards and fuse-holders of various types, hand lamps, connector plugs, insulated lamp-holders, and small switches to obviate the necessity for earthing, insulated standard lamp-fittings suitable for engineering shops, &c. Amongst the station apparatus were switchboards for high-tension working arranged so that the conductors and apparatus in the several compartments could be made dead and absolutely screened off from any live conductors for cleaning or repairs, &c. High-tension generators and motors with a form of guard designed to protect the coil ends in such a way that they could not be touched, while at the same time allowing of ample ventilation, were also shown. A new fire-resisting insulating material suitable for switch covers, fuse boxes, lamp-holder covers, &c., has recently been introduced, and appears to be well suited for these and other purposes where fireproof qualities are important.

A novel and useful electrical appliance for controlling cranes in the loading and unloading of ships, and which seems likely to be extensively adopted for this and other purposes, not only on account of its efficiency for the work, but also on account of greater safety to the workmen employed, was brought to my notice during the year. It has been already applied to the control of both electric and hydraulic cranes. The driver stands at a convenient point beside the hatchway, whence he can see into the hold. He is provided with a small drum-shaped controller slung from his shoulders, and he can move about freely as he likes. He therefore has the load in sight from the bottom of the hold until it is deposited upon the quay, railway wagon, or barge. The controller, which is connected to the crane by a flexible armoured cable, is provided with two handles, one for controlling the hoisting and lowering motions, and the other for slewing. There is also an emergency button by which the current can be cut off and the crane brought instantly to rest. The crane motors are operated through a system of contactors which are controlled from the portable controller by means of a comparatively small current at a low voltage. Thus the crane motors

may be worked from a 500-volt supply, whilst 100 volts only may be used in the portable controller, a small motor generator being placed in the crane cabin for providing the low-voltage current. The operation of the cranes in this way is very interesting to watch. The most striking features are the perfect control of the load and the fact of the crane cabin having no occupant the whole operation appears to be automatic.

It is well known that persons having received a severe electric shock and having been rendered unconscious and apparently dead, have been, in a number of instances, restored by means of artificial respiration, in some cases only after the treatment has been continued for a considerable time. The success of the treatment probably depends a good deal upon the care and skill with which it is carried out. In any case the process, if continued for any length of time, as it should be if necessary, may be very laborious, particularly in the case of the Sylvester method, unless there is ample assistance at hand. In order to facilitate the treatment and render it at the same time more effective, an apparatus has been devised by Dr. K. A. Fries, of Stockholm, and has been recently introduced into this country. It has already been adopted at a number of important electrical stations. The apparatus is designed for carrying out the Sylvester method, in which the patient is placed on his back, his arms being

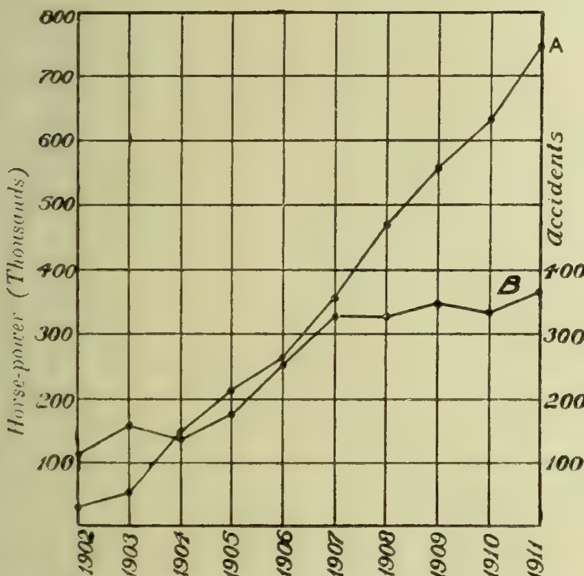


DIAGRAM SHOWING (A) STEADILY INCREASING USE OF ELECTRICAL ENERGY FOR MOTIVE POWER IN FACTORIES DURING THE LAST 10 YEARS, AND (B) CHECK IN THE INCREASE OF ELECTRICAL ACCIDENTS SINCE 1907.

moved up and down while pressure is brought to bear on the chest in synchronism with these movements. It is claimed that a person can operate the apparatus with one hand, leaving the other free to draw forward the tongue of the patient. It would appear, however, that the apparatus might be readily adapted to the Schäfer method, which is now generally considered by medical men to be superior, one reason being that the patient being placed face downwards the difficulty of the tongue blocking the air passages is obviated. In this connection it is interesting to note that a representative committee of American doctors and electrical men, who recently considered the merits of the different methods, have unanimously recommended the Schäfer method.

The continued increase in the use of electrical energy for motive power in factories is again indicated by the figures taken from the annual returns of horse-power of motors connected to the mains of electricity supply undertakings published by "The Electrician." Although the figures are not complete—a number of undertakings giving no return and the large power companies not being included—an addition of 115,000 h.p. is accounted for during the year, bringing the known total of motors connected to public supply mains up to 744,000 h.p., the increase being larger than has been shown in any previous year.

This being the tenth annual report which I have had the honour to present, it is interesting to note the progress which has been made in the use of electrical energy during the 10 years. The attached diagram shows that the horse-power of motors connected to public supply mains, and consequently the use of electrical energy for motive power purposes in factories, has been a development which has taken place almost entirely during that period. On December 31st, 1902, the horse-power of motors so connected (taken from the same source of information) was only 30,000, whereas on December 31st, 1911, it had gone up to 744,000, or 25 times the amount. The actual total for all factories is, no doubt, much larger, as owing to the incompleteness of the tables a number of important districts are omitted, and factories generating their own electrical energy are not included. It is also interesting to note the yearly totals of electrical accidents indicated on the same diagram. Whilst the number of accidents was steadily increasing up to the end of 1907, it has since remained almost stationary. It is further interesting to note that the check in the increase of the number of accidents occurred in the year following the issue of the draft regulations, and in which the attention of occupiers and engineers was further drawn to the consideration of questions of safety by the public enquiry. Had the accidents continued to increase at the same rate and in accordance with the increasing use of electrical energy, they would now have reached more than double the number actually recorded. The results are even more favourable than is indicated by the diagram, as there are now included for the first time accidents occurring at electrical stations of purely traction undertakings.

TABLE III.—*Electrical Fatalities reported under the Factory Acts in* 1911.

No. (1)	Month. (2)	District. (3)	Voltage of system. (4)	Voltage of Circuit or probable voltage of shock. (5)	System. A = Alternating, 1 = Single-phase, 2 = Two-phase, 3 = Three-phase, D = Direct. (6)
1	February ..	South London	10,000	10,000	A 1.
2	April	Newcastle ..	580	*	D.
3	July	Newcastle ..	440	250–440	A 3.
4	July	Glasgow	250	. 250	D.
5	July	Newcastle ..	20,000	12,000	A 3.
6	July	Manchester ..	10,000	6,000	A 3.
7	July	Birmingham	2,100	2,100	A 2.
8	August	Stockton	440	250–440	A 3.
9	August	Newcastle ..	440	250–440	A 3.
10	October ..	South London	2,200	2,200	A 1.
11	December	South London	220	125–220	A 3.

* Burns, not shock.

MOTION STUDY.*

BY CHARLES S. MILLER.

MOTION study is a valuable and useful instrument to use in performing the operation of cutting costs. It is also a dangerous instrument, this on account of two principal reasons: (1) It takes time to make motion studies, and a great deal of money can be very quickly spent in making observations which may develop later as having little or no practical value. (2) Unless the workmen are handled right, they are apt to get the impression that the studies are being made with the sole purpose in view of cutting rates.

In the mind of the uninformed there is apt to be some confusion between motion and time study. We might say the former is qualitative and the latter quantitative. Motion study analysis determines the proper elementary motions necessary to accomplish a certain act. It eliminates all unnecessary motions and determines the arrangement of the work to enable the operator to execute the sequence of motions with the least expenditure of effort and time. It is a motion study that effects savings.

Time study is measure; it determines standards by which we can measure the relative efficiency of the old and new methods. It serves as the basis in setting prices on piece work or the standard time on bonus work. Time study is complementary to motion study. It is necessary so that we may establish standards which must be lived up to by the operator, and these standards can only be reached by operators working under this new method.

* Abstract of paper read before the American Supply and Machinery Manufacturers' Association, May 13th, 1912.

To the average workman it seems too much trouble to make the effort to break away from the old method of doing his job and working his mind long enough to create brain channels that will telegraph the new motions to his hands. Written instructions, wage incentive, personal direction, and, for a time at least, constant supervision, are all necessary. In the case of much foreign labour the work must be done without the written instructions to the workman. After a time increased wage return, less fatigue, and the habit formed of doing the work in the correct way, ensure the performance of the operation in the standardised manner. The matter of training workmen in habits of industry, in the doing of their work in the proper manner, has a humanitarian as well as a commercial aspect.

One feature of time study is worth mentioning, though it is opposed to the fundamental principle of mutual confidence between employer and workman; it is practically impossible for an operator to fool an experienced motion and time study man by "soldiering" on a job under observation. Five to ten timings of the elementary motions in an operation, establishing a standard time for each motion, not an average, and summing the unit standard times, will invariably give a fair total time for the complete operation. In addition to establishing a standard method of accomplishing a job, motion study brings the individual workman under close observation, and this enables the employer to fit the workman to the job. It makes possible the consideration of the personal equation of the operator in selecting him for a certain operation. I will now give examples of motion study taken from actual practice. Comparatively simple operations have been chosen, both on account of the greater clarity in description and because it is in the simpler operations that often lies the opportunity of greater economy in movement rather than in ones of more complexity.

Making final sizing cut on taps and gauging diameter of top and bottom of threads. The cut is made on a vertical drill press with a die set in the bedplate, and the tap is gripped in the chuck and forced down through the die, falling into a pan under the press. The work is gauged in two "pass and stop" gauges placed on the left of the bed of the press. By the old method the unfinished work was in a box on the left of the machine; the finished work in a box on the right. The sequence of motions was as follows:—

(1) Reach 2ft. to left of box of unfinished work.
(2) Pick up tap with left hand.
(3) Bring tap to chuck.
(4) Slip squared end of shank into chuck with left hand.
(5) Reach over with right hand and lower head of press, passing tap through die until it falls into pan under press.
(6) Reach under press with left hand and pick up tap.
(7) Lift tap from pan to gauges on left of press.
(8) Pass through gauges.
(9) Transfer tap from left hand to right hand
(10) Put in box of finished work.

Now for the new method. The box of unfinished work was placed closer to the operator, and the box of finished work placed beside it on the left side of the press. A small sheet-iron chute was placed under the press so the tap would slide to the front when it fell from the die. The right hand of the operator grips the lever of the head continually. A better arrangement would have been to put an attachment on the press, to actuate the head by foot, but this change was not made in this instance.

Starting with the operator gripping this lever with his right hand and his left in the box of finished work where he has just placed his last finished piece, the new sequence of motions is as follows:—

(1) Move the left hand about 6in. towards the chuck to the box of unfinished work.
(2) Pick up tap with left hand.
(3) Bring tap to chuck.
(4) Slip squared end of shank into chuck with left hand.
(5) Lower head with right hand, passing tap through die. While doing this with the right hand, execute the following motions with the left:—
(*a*) Pick up previous tap from pan between knees.
(*b*) Lift tap to gauges.
(*c*) Pass through gauges.
(*d*) Reach to box of finished work and lay down tap.

In this operation a saving of 50 per cent. in the time was effected by the new method. A 6s. a day man was sizing about 700 pieces per day, costing the company about 10½d. per hundred. By setting a piecework rate of 7d. per hundred, the operator was able to earn approximately 8s. per day by the new method, and the company saved one-third of the direct labour cost of the operation.

Operations of grinding reamers to a gauge size, there being required two grindings, the roughing and finishing. The grinding was being accomplished in two distinct operations, the grinder being set first for the roughing grind and a lot of several hundred put through, then changed for the finishing grind and the lot put through the second time. The work was placed in a dog, inserted in the carriage chuck, clamped, and the carriage travelled forward and back automatically. During this time the operator took the dog off the last accomplished piece of work, put this piece in a box, picked up another piece of work, put on the dog, then "sat" until the grinding was finished.

By the old method the sequence of motions and the unit time of each motion was as follows:—

(1) Pick up reamer and attach dog	0·09 min.
(2) Stop machine, take out and put in work, and start machine	0·13 min.
(3) Grinding (automatic)	0·30 min.
(4) Remove work from dog and put in box	0·07 min.

Operations (1) and (4) are accomplished during (3), so that the elapsed time for one cycle of operations was 0·43 mins., during which the operator was idle 0·14 min., or one-third of the total time. Thirty-three and one-third per cent. rest in this instance was very considerably more than a man required to work without undue fatigue. The problem was how to utilise this idle time—0·14 min. in every 0·43 min.

As two grinds were necessary to bring the reamers to final size, the sequence given above was repeated, the machine being readjusted after the first lot was finished. It will be noted then that the total time for the two grinds on each piece, exclusive of any time for machine set-up or adjustment, personal needs of the operator, &c., was $2 \times 0{\cdot}43$, equal to 0·86 min. As this example is for comparisons of the actual machine time between the old and new methods, the factors outside of this are not discussed here, though careful study would have to be made of same before setting a standard task.

By the new method the operator will be provided with two machines, indicated hereafter as machine R for roughing grind and machine F for finishing grind. The machines should set face to face about 4ft. apart. Starting at machine R, the sequence of motions and the unit times of same would be as follows:—

At Machine R.	
(1) Pick up reamer and put in dog	0·09 min.
(2) Stop machine, take and put in work, and start machine	0·13 min.
(3) Grinding (automatic)	0·30 min.
(4) Turn and step to Machine F	0·02 min.
At Machine F.	
(5) Stop machine, take out and put in work, and start machine	0·13 min.
(6) Grinding (automatic)	0·30 min.
(7) Remove dog and put finished reamer in box	0·07 min.
(8) Step to Machine R	0·02 min.

Remembering that operations (3) and (6) are automatic, we find the sum of the time of the other operations to be 0·46 min. for completing both grindings.

The comparison would consequently be as follows:—

Old method time per 100 pcs., two grindings	83 mins.
New method time per 100 pcs., two grindings	46 mins.
Saving	37 mins.

Per cent. time saved ...... 44½.

In this particular case two additional factors must be considered: (1) Will the volume of work be sufficient to bring justifiable returns on the investment in one additional machine. (2) What percentage of time will the machines lie idle between the time the grinding is automatically completed, and the workman gets the machine started again. In this case we find that it takes the workman 0·33 min. to

complete his cycle of operations from the time the machine is started until he returns to unload and load the machine. As the automatic operation requires only 0·30 min., there will be 0·03 min. lost on each machine on each operation, or the machine efficiency will be 91 per cent. as compared with the old methods.

Assuming that there is sufficient work to keep both machines busy, that each machine costs £50, and that 20 per cent. of this cost is the yearly charge for repairs and depreciation, we find the yearly cost of the additional machine to be £10. A 10d. per hour man was doing this work. His income, working full time, would be £115 per year. Deducting 20 per cent. from this as the amount paid for unproductive time, that is, time for setting and adjusting machines, personal needs, &c., and taking 44½ per cent. of the result, we find a saving in labour by the new method of £42 per year. Deducting the £10 machine cost, the company would save on this one simple operation £32 per year.

ERRORS IN THE USE OF PURE MANGANESE IN ALLOYS.

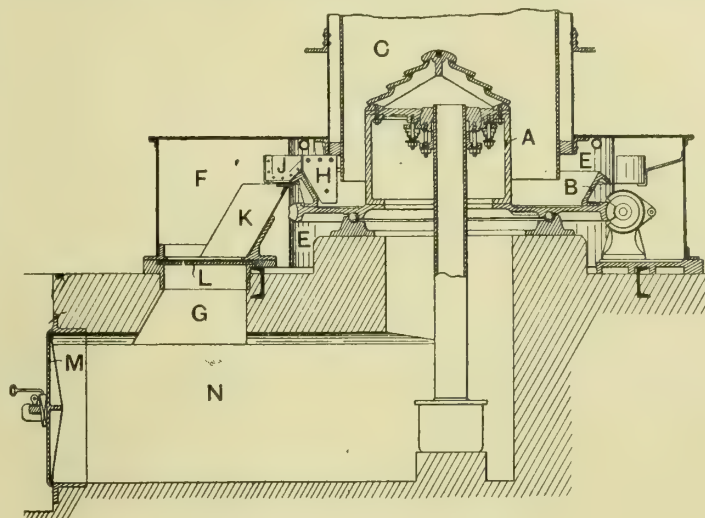
THE use of metallic manganese as a deoxidising material in metal and alloys has now become quite extensive. It has been found particularly efficacious in the nickel alloys, such as German-silver or cupro-nickel. While the best method of using the manganese in such alloys is to introduce it as manganese-copper, for the reason that not only can this material be purchased of high purity, but it also renders the introduction of the manganese positive, many persons prefer to purchase the pure manganese and use it in the nickel alloys. Unless this pure manganese is added in the right manner the results are uncertain, and it has been found that makers of nickel alloys have been obtaining results lacking in uniformity simply because the manganese was not introduced into the molten metal in the right manner. It has been added directly to the metal after the latter has melted. This is wrong, as will afterwards be explained.

Pure manganese melts at about the same temperature as steel, which, it will be appreciated, is very much higher than that of the German-silver or other nickel alloys. On this account, when it is added to the molten metal, it does not melt, but remains on the melted mass in its original condition. When the crucible is skimmed, therefore, the manganese is removed with the skimmings. In regard to this difficulty, there are some persons who believe that the manganese, although it has a much higher melting point than that of the German-silver or other nickel alloy to which it is added, will gradually dissolve and so enter the alloy. While this is undoubtedly true, provided the manganese is left in the molten metal sufficiently long, the period which elapses, after the manganese has been introduced, is so short that very little dissolves. Even though it may, the results are not positive and the quantity of manganese that enters the metal or alloy is variable and uncertain.

The best method of adding manganese to copper or copper alloys, is first to make a rich copper and manganese alloy, and then use this for adding to the German-silver or other copper alloy to be treated. This procedure enables the manganese to be introduced with certainty for the reason that the copper and manganese alloy melts at about the temperature of the German-silver or other alloy. It then diffuses itself through the metal shortly after it melts. The common method, and one which gives satisfactory results, is first to make a copper and manganese alloy containing 70 per cent. copper and 30 per cent. manganese. The manganese and copper are melted together in a crucible at a heat sufficiently high to melt the manganese, after which the mass is stirred and poured out into small bars so that they can readily be cut into small pieces. This copper and manganese alloy (called manganese copper or often cupro-manganese) is added to the metal or alloy in the proportion of about 5 oz. to 100lbs. of the molten metal. While it can be introduced after the metal has melted, far better results are obtained if it is added when the metal is put into the crucible and it is allowed to melt with the other metals. This gives the manganese a far better opportunity to act. The manganese then begins to do its work as soon as it melts.—"The Brass World."

ROTARY GRATE FOR GAS PRODUCERS.

ROTARY grate gas producers, of the kind in which a rotating pan, provided with a water seal and arranged at the bottom of a stationary shaft carries the rotary grate which is formed with blow holes for the air, give an excellent effect when pressures are used which do not much exceed the atmospheric pressure, but if higher pressures are used the water seal arrangements usually prove insufficient, especially with respect to the ash discharge. This will be readily conceived from the fact that the pan must have a considerable height, as the water on the outside will rise to a point corresponding to the pressure within the shaft. Of course a pan of that kind renders a continuous discharge of the ashes very difficult or even impossible, the discharge of the ashes out of the pan requiring a reduction of the pressure and thereby decreasing the output of the producer and interfering with its regular and efficient working. To remove the difficulties arising in connection with the high pressure blast the design of grate illustrated herewith has been patented by Anton von Kerpely, Kaiser Wilhelmring, 16, Vienna I., Austria. In this design the water seal is dispensed with, the rotary pan being housed in an air-tight chamber which prevents communication with the outer atmosphere. An advantage in enabling a water seal to be dispensed with



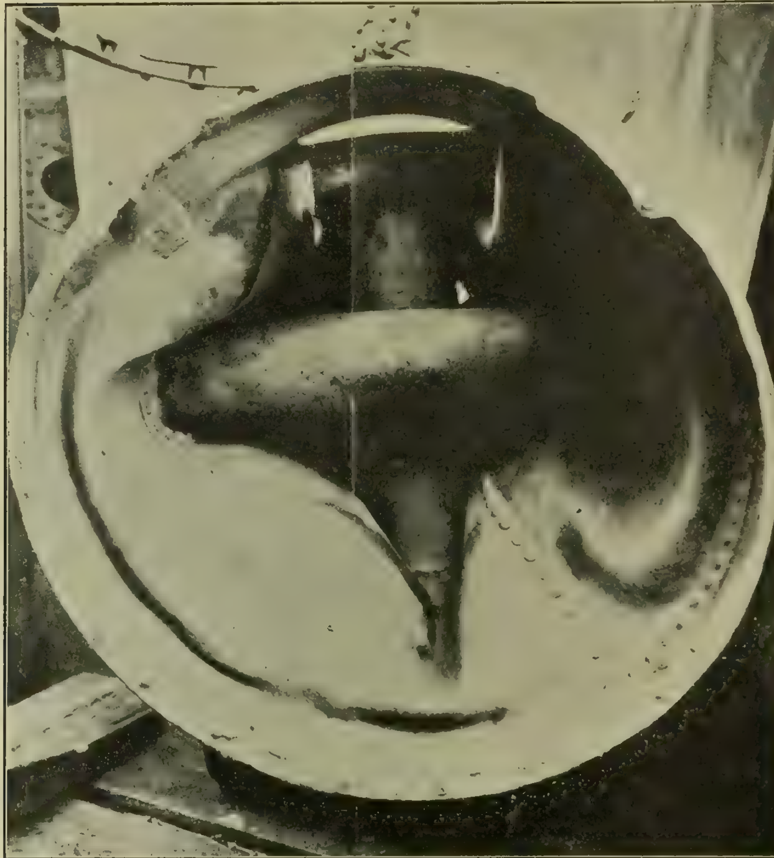
ROTARY GRATE FOR GAS PRODUCERS.

is that the gases generated in the producer are not liable to be impaired by becoming charged with water vapour.

The illustration shows a section representing the lower part of a gas producer. The rotary pan B carrying the grate A and arranged to act in conjunction with an ash-discharging device is housed in an air-tight chamber E communicating with the producer shaft C and cutting off communication between the latter and the atmosphere, this chamber being constituted by a sheet-iron casing forming an air-tight joint at the top with the outer casing of the producer and at the bottom with the foundation. At the bottom of an extension F of the chamber E is an ash passage G. The ashes are delivered over an inclined shoot K by means of ash-discharging apparatus comprising a collecting abutment surface or plate H and conveying scoop J. The shoot K leads the ashes into the ash passage G, the upper end of which is adapted to be closed in an air-tight manner by a slide L, and the lower end of which communicates with a collecting chamber or ashpit N adapted to be closed in an air-tight manner at the outer end by a door M. In this way the ashes accumulating above the retaining or closing slide L may be from time to time discharged into the air-tight ashpit by opening the retaining slide without reducing the pressure of the blast in the producer shaft and interfering with the proper working of the producer. Upon the ash passage being closed the ashpit can be opened and the accumulated ashes removed. To prevent air escaping past the ball bearing of the rotary grate a sheet-iron baffle fixed to the base is arranged to co-operate with an annular rib on the underside of the pan bottom.

SOME RECENT BOILER FAILURES AND THEIR LESSONS.

A Disastrous Result of Shortness of Water.—Board of Trade Report No. 2,115 gives particulars of a disastrous vertical boiler explosion which occurred on board the barque "Indian Empire," on November 23rd last, while lying at the Junction Lock, Cardiff, and resulted in three men being killed and two others severely injured. The boiler, which measured 8ft. in height by 4ft. 6in. diam., was of the ordinary type, fitted with



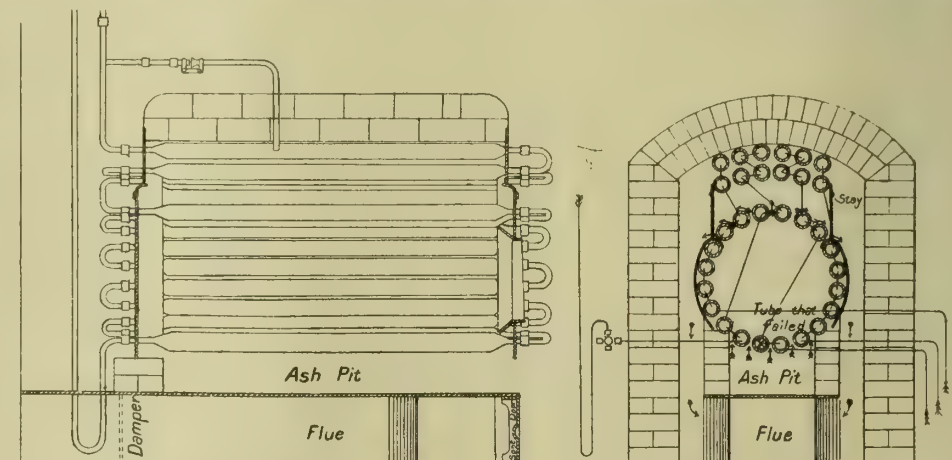
REPORT No. 2,115.—VIEW OF BOILER, SHOWING COLLAPSED FIREBOX.

a central uptake and two cross water pipes, and the cause of the failure was overheating of the firebox from shortness of water, due apparently to the gauge glass deceiving the attendant by giving a false water level. As a result of the overheating the firebox collapsed badly between two of the cross water pipes, and ruptured, as shown in the accompanying photo view. The explosion shows the importance of always fitting boilers with glass water gauges in duplicate, so that one may serve as a check on the other, and also wherever possible of equipping boilers with a fusible plug. Had the boiler in question been supplied with a fitting of this kind, it is more than probable that the explosion would have been prevented.

Plug Taps versus Valves in Water Gauge Connections.—In land practice it is the almost invariable custom to use plug taps for opening or closing the connections to glass water gauge fittings, and a similar practice very generally prevails in marine work, though many marine engineers prefer valves to plugs. There is no doubt, however, that valves are less positive in their action than plugs, and more liable to derangement, and a failure illustrating this is recorded in Board of Trade Report No. 2,116, which relates to a case of shortness of water brought about through the valve becoming detached from the screwed spindle. As a consequence, a false water level was indicated, which deceived the engineer in charge. Fortunately the only result of this was to cause the steam in the boiler to become superheated and destroy the jointing material of the stop valve chest, and this, fortunately, led to a leakage, which called attention to the danger before further damage was done. We have, however, known of instances which did not end so happily, and it is to be trusted that the publicity of this case will lead superintending engineers who have charge of arrangements in which water gauge connections are fitted with screw-down valves, to replace such fittings by plug cocks, which, as the Board of Trade Report points out, are less liable to cause trouble than valves.

Steam Trap Connections.—Steam traps for automatically draining water from steam apparatus or ranges of pipes are useful fittings; but in many cases steam users do not give them proper attention, with the result that their action is often imperfect, and we can recall many instances where accumulations of water resulting from such imperfect action have led to serious failures. Like any other piece of mechanical apparatus, these fittings require occasional overhaul and supervision, and it sometimes happens these fittings are rendered inoperative through being wrongly connected to the apparatus they are intended to drain, as in a case recorded in Board of Trade Report No. 2,119, where an accumulation of pressure burst the trap and caused injury to a man who was near. Had the trap been properly connected the accident would probably not have occurred; but apart from this, it is desirable in the interests of safety that steam traps should, in all cases where there is risk of their being exposed to full boiler pressure, be made capable of resisting such pressure, especially as this can be done at the expenditure of very little material or expense.

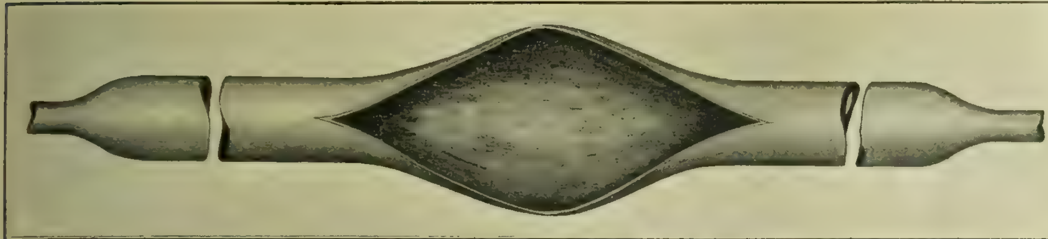
Failures of Hot-water Circulating Boilers.—Users of hot-water circulating boilers often treat them as harmless apparatus owing to the comparatively low pressure at which they are worked, and to the belief that they cannot result in violent and dangerous explosion. The folly of this belief has often been shown, and two further pertinent illustrations are afforded by reports Nos. 2,132 and 2,135. Both the explosions occurred in February last, during a period of frost, and were due to excessive pressure caused by the thoroughfares in the circulating pipes being blocked with ice. In the first, which occurred at Birmingham, the boiler consisted of a tubular arrangement, as illustrated. Under normal circumstances, the tubes, owing to their small diameter, would be capable of resisting very great pressure, a fact which erroneously leads many users to believe they are immune from explosion. When full of water and hermetically sealed, however, it requires very little overheating to cause the development of enormous pressure, and in the case under notice this led to a very violent explosion, as will be evident from the fact that the enclosing brickwork of the boiler was destroyed, along with its cast-iron framework, while an adjoining wall was blown down and a fire started, which wrecked the works. All this



REPORT No. 2,132.—VIEWS OF HEATING BOILER, SHOWING POSITION OF TUBE THAT FAILED.

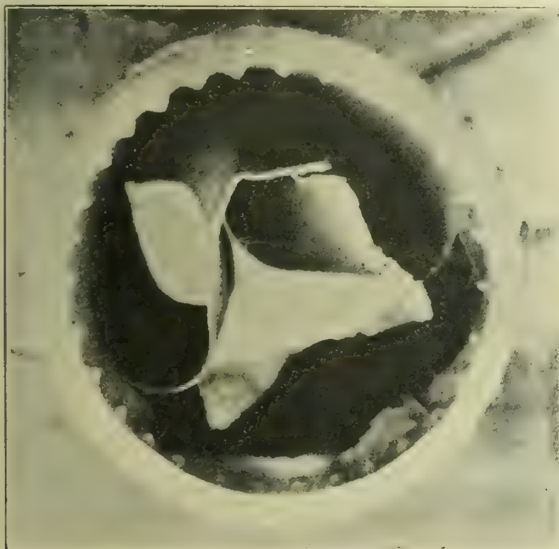
occurred from the bursting of a tube which was only $3\frac{1}{2}$in. in external diameter, and which was torn open longitudinally, as shown in the photo view, for a length of 19in. In the case of Report No. 2,135, the boiler was of a different construction. It was practically a conical annulus with the fire inside, about 3ft. 10in. high by 26in. diam. at the bottom and 20in. at the top, as shown in the accompanying illustration. In this

instance, the weak point of the structure was the internal casing which, under the influence of the excessive pressure, brought about by the choking of the pipes, collapsed and tore away from the block ring at the bottom as shown in the photo view. In neither of these cases, it may be observed, was a safety valve fitted, nor were the boilers subjected to competent inspection. Had the latter precaution been observed, the defect in their equipment would, no doubt, have been pointed out, and the failures prevented.



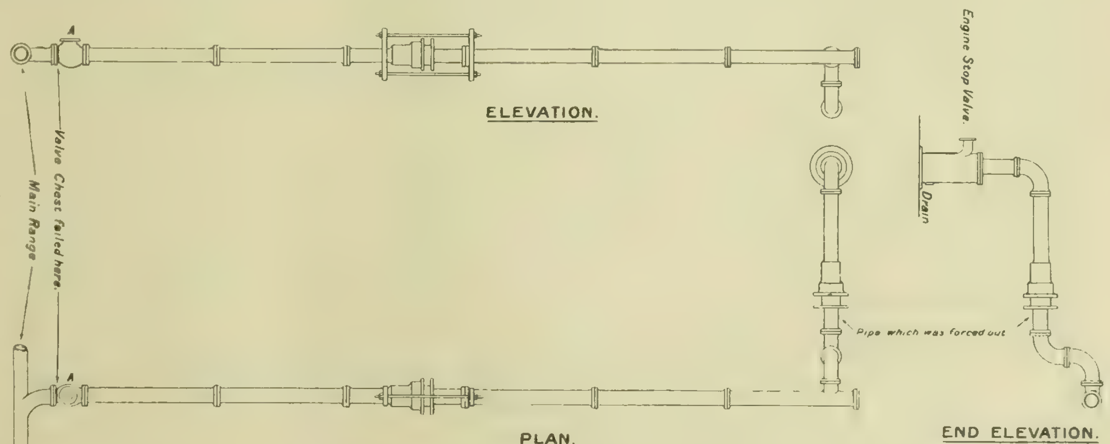
REPORT No. 2,132.—EXPLOSION OF A HEATING BOILER. ENLARGED VIEW OF DEFECTIVE TUBE.

The Importance of Guard Bolts for Stuffing-box Expansion Joints.— While the necessity of providing for expansion in long ranges of steam pipes is generally recognised, steam users sometimes overlook the importance where such an expansion arrangement

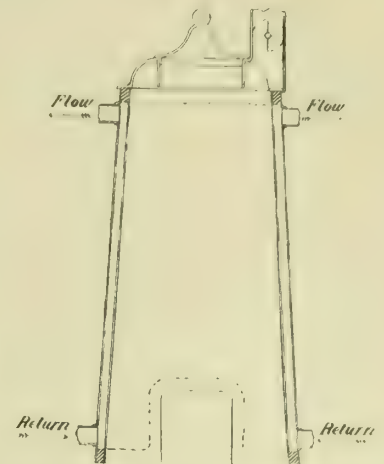


REPORT No. 2,135.—EXPLOSION OF A HEATING BOILER. VIEW SHOWING COLLAPSED FIREBOX.

consists of a stuffing-box device, and the ends of the length of piping are not anchored fast, of providing guard bolts to prevent the two parts being drawn asunder. The danger arising from the absence of such a provision is illustrated in a Report, No. 2,138, referring to a failure which occurred at a tinplate works in Glamorganshire on March 16th last. There was a short length of pipe between the engine stop valve and the steam main leading to the boilers. The steam main and the short length were each fitted with a stuffing-box arrangement, but while that in the main was furnished with guard bolts, the short branch piece was not so provided, and as soon as the pipes were put into operation, the two parts of the short length were drawn asunder and allowed steam to escape, scalded a labourer who was assisting on the job. The action which took place, and the desirability of fixing guard bolts in all such arrangements, will be readily apprehended on reference to the accompanying diagram, which shows the arrangement of the pipes in question.



REPORT No. 2,138.—VIEWS SHOWING ARRANGEMENT OF STEAM PIPES.



REPORT No. 2,135.—SECTIONAL VIEW SHOWING ARRANGEMENT OF HEATING BOILER.

NEW SINGLE-PHASE RAILWAY MOTOR.

AT the recent summer meeting of the Institution of Electrical Engineers a description, with demonstrations, of a new form of single-phase motor with pole-changing winding was given by Mr. J. S. Nicholson and Mr. B. P. Haigh. This motor is fitted with pole-changing windings, and is worked as a repulsion motor with eight or four poles alternatively, according to the speed required. Up to half-speed, 500 revs. per minute, the eight pole connections are employed, while for higher speeds the windings are changed over to four poles, and the field is obtained by passing a magnetising current through the armature. As a repulsion motor works best when running at a speed close to synchronous value, the use of the pole-changing winding allows of the best results being obtained over a wider range of speed than usual, as two synchronous speeds are available. The motor is started with the greater number of poles, and as the flux per pole is thus reduced to one-half the usual value the voltage induced in the armature turns is considerably reduced and a much greater starting torque is obtainable without sparking. With eight poles the motor can be started against full torque almost sparklessly, while on the other hand, with four poles the sparking is excessive. By taking advantage of this improvement it should be possible to build motors of greater output within given overall dimensions, as less space is required in the commutator and windings than with the standard type of repulsion motor. The action of the pole-changing motor when running at full speed is similar to that of other "compensated-repulsion" motors; thus the power factor approximates to unity, and the motor may be used with shunt connection, in which case regenerative braking may be employed.

THE CORROSION OF IRON AND THE PROTECTION OF STRUCTURAL IRONWORK.*

BY L. ARCHBUTT, F.I.C.

(*Concluded from page 10.*)

ONE of the most successful methods for the preservation of underground iron was patented many years ago by the late Dr. Angus Smith. In this process, as described by the author in his specification, coal tar is boiled until all the water, the ammoniacal liquor, and the lighter oils are expelled, and the prepared tar is applied to the cast iron fresh from the mould. The process was invented for the preservation of water pipes. The pipes are taken immediately they have been cast, before they have had an opportunity of rusting or acquiring any moisture, and after fettling they are put into a stove and brought to a temperature of 300° Fah. They are then lowered in a perpendicular position into the prepared tar, heated to the same temperature and left there for a sufficient time for the hot and fluid tar to thoroughly soak into the pores of the metal; then lifted out and allowed to drain. This process is carried out at all the large iron works in this neighbourhood where pipe making is carried on. If properly done the coating on the pipes, when cold, is tough, and not brittle or soft enough to be seriously damaged in the handling of the pipes. They should be laid in the ground soon after treatment, and not stacked for any length of time, as the action of the sun and air tends to make the coating become brittle and shell off. At one works where I saw the process carried out, the hot pipes, after lifting out of the tar tanks, were rolled down a gantry, which made a spiral mark through the coating, exposing the iron, which rusted along the spiral groove. Like many excellent and simple processes, this has suffered at the hands of improvers, and one finds lime and other things added to the tar. I believe Dr. Smith does mention the addition of linseed oil to the tar in his specification, but I have never seen it added, nor does it appear necessary if the tar is good and properly prepared, and he does not mention lime. One also finds the term "Dr. Angus Smith's solution" in engineering specifications, but Angus Smith suggested no solution, and the use of tar varnish laid on with a brush was not his process at all, nor is so good a protection for the iron obtainable by any such means.

The action of water upon iron in hot-water pipes and in steam boilers is very different. In the former, the carbonic acid is retained in solution in the water; in the latter, the gas is given off freely. Many years ago my attention was directed to serious corrosion of the wrought-iron hot-water service pipes at an hotel in Leeds. It was noticed that the hot water, when turned into the baths and lavatory basins was either red in colour or rapidly became so on exposure to the air, and deposited a red sediment. I obtained a piece of 1½in. wrought-iron pipe, 12in. long, and had it welded up at one end. The open end was closed with a rubber stopper, through which a straight glass tube was passed. The iron pipe, having been thoroughly cleaned inside, was filled with Leeds water quite full, and the stopper was inserted until the water rose in the glass tube. The iron pipe was then placed upright in boiling water. After 10 minutes the stopper was removed, and the water when poured out into a white basin was found to have a strong red colour. Some more of the water was then saturated with CO_2 and heated in the pipe. A large quantity of hydrogen gas was now expelled through the glass tube, owing to the reaction $Fe + H_2CO_3 = FeCO_3 + H_2$. On removing the stopper and pouring out the water this time it was found to be nearly clear and pale greenish in colour. It almost immediately began to oxidise and turn red, and in a few hours deposited a bulky precipitate of red ferric hydroxide. A similar experiment was made with Leeds water which had been thoroughly boiled to remove all CO_2, and in this case there was little or no action on the pipe. It became evident, in fact, that all the trouble was caused by the carbonic acid in the Leeds water, and the fact that the water was so soft as to deposit no protective coating of carbonate of lime in the pipes. It was proved that the water had no perceptible action on copper. The iron service pipes were, therefore replaced by copper, since when there has been no further trouble.

Another curious case came under my notice more recently. An hotel in London was supplied with New River water, which is a hard water containing carbonate of lime, and this caused a good deal of trouble by depositing the carbonate of lime inside the hot-water service pipes and choking them up. In course of time a borehole was sunk into the chalk beneath the London clay, and a very soft water was thus obtained, which was supplied to the hotel instead of the New River water. Some time afterwards complaints were received that the soft water was corroding the pipes, and, in fact, in six years some of the wrought-iron pipes were entirely corroded through by it. No corrosion had been noticed with the New River water, and it was, therefore, concluded that the borehole water was corrosive and the other water was not. I found, however, by experiment that the facts were quite the reverse. Weighed strips of polished hoop iron were placed in glass flasks filled with the two waters, one pair of flasks being heated and the other allowed to stand at the ordinary temperature. After 23 hours the strips were taken out, carefully cleaned, and weighed. The following results were obtained:—

	Loss of Weight (gramme). At ord. temp.	At 212° Fah.
In well water	·0044	·0042
In New River water ...	·0090	·0157

The New River water was thus proved to be the more corrosive of the two, but the pipes had been protected from this action by the carbonate of lime deposited in them. The soft borehole water, however, which deposited nothing to protect the iron, was enabled to exert a serious and continuous corrosive action, and thus in practice proved the more corrosive of the two.

All natural waters when heated in wrought-iron pipes may be expected to exert a corrosive action on the iron at first, and whether the action continues will depend entirely upon whether the pipes do or do not become protected by a deposit of carbonate of lime. Galvanising will protect the iron so long as the zinc coating lasts, which will not be for long, but in the case of hard chalk waters it will probably last quite long enough to preserve the iron from corrosion until the protective coating of carbonate of lime has formed, and will, therefore, prove advantageous for such waters. Steel* reports a case where Green's economiser pipes of cast iron were dissolved away by the soft water of Sydney, N.S.W., in a few months, only a thin outer shell remaining. About 84·5 per cent. of the iron and the whole of the combined carbon and sulphur had disappeared, and a residue remained in the pipes containing the whole of the graphite, phosphorus, and silicon, the latter as oxides, which formed a thick layer of plumbago-like material on the inside of the pipes.

It makes a great difference whether there is a continuous flow of fresh hot water through the pipes, as in hot-water service pipes, or whether there is merely a circulation of the same water, as in heating pipes. In the latter case, the carbonic acid and oxygen are not renewed, and the corrosive action, which is slight, soon comes to an end. One, therefore, never hears of the corrosion of heating pipes, the life of which is indefinitely long.

In steam boilers a quite different set of conditions prevails. Here the carbon dioxide and oxygen are rapidly expelled from the water, and their corrosive action is greatly lessened, though not entirely removed, for the feed water added continually renews these gases, and consequently they are never entirely absent, and hence their injurious effect on the iron, though more slowly, may be none the less surely produced. In boilers, however, other phases of the question present themselves, such as the corrosive action of saline solutions at high temperatures, the influence of impurities in the boiler plates, the effects of strain, and of the contact of dissimilar metals.

It is a well-known fact that all waters are not equally corrosive, and that the corrosivity depends upon the nature

* Paper read before the Derby Society of Engineers.

* Jour. Soc. Chem. Ind., 29 (1910) 1141.

and amount of the dissolved salts. Very soft waters, such as that of Loch Katrine, for instance, contain such a trifling quantity of matter in solution that they deposit next to nothing on the boiler plates, which remain freely exposed to attack by the dissolved gases. The amount of corrosion that goes on is then dependent upon the amounts of carbonic acid and oxygen brought in with the feed water, and also upon the composition of the steel or iron boiler plates. Most waters, however, contain salts in solution. Some of these salts, which make the water hard, *i.e.*, destructive to soap, deposit carbonate of lime, magnesia, and sulphate of lime as a crust upon the plates, which protects them from corrosion less or more according to whether the incrustation is soft and porous or hard and non-porous; other salts, generally the sulphate, chloride, and carbonate of sodium, do not deposit but remain dissolved, and, as the water is evaporated, form a corrosive solution of increasing strength. Softened waters, which have had their incrusting salts removed by chemical treatment, leaving the soluble salts in solution, and perhaps even increasing their amount, are more liable to attack the plates than the hard water, and care has to be taken not to remove the whole of the incrusting salts, lest by so doing the plates should be exposed to corrosive attack, and the evils caused by excessive incrustation replaced by another and perhaps greater evil. Cribb and Arnaud in 1905* and Heyn and Bauer† more recently have shown that dilute solutions of sodium or potassium carbonate stimulate corrosion, and waters which are softened by sodium carbonate may thus be rendered actively corrosive if the sodium carbonate be used in excess. As the amount of the alkali increases, the corrosivity increases up to a certain concentration, and then diminishes again, and we have the remarkable fact that strong solutions are protective to iron, whilst dilute solutions are actively corrosive.

It is only within the last four years that the action of saline solutions upon iron has been systematically studied, by Heyn and Bauer‡ in Germany, and by Friend and Brown§ in this country. Heyn and Bauer have studied the action at ordinary temperatures of many of the most commonly-occurring salts, in solutions ranging in strength from highly dilute to saturated solutions. Their results are capable of being represented diagrammatically by a curve. The general effect of dissolving any single salt in distilled water at ordinary temperature is to make it more corrosive to iron. If the corrosive effect of distilled water be so much the addition of a soluble electrolyte increases the action up to a further point which is called the "critical concentration," beyond this the corrosive effect diminishes as the concentration increases, until it becomes nil, and from this up to the saturation point the solution is actually protective. In the great majority of cases, however, the nil point is never reached; in other words, the water becomes saturated with the salt before the corrosivity of the solution ceases, and the curve, therefore, terminates at some earlier point.

Solutions of chromic acid and chromates are exceptional, in that they have no "critical concentration," and tend to be protective from the first. Cushman has applied this fact in practice to the preservation of fence wire in America by passing it through a solution of potassium bichromate of suitable strength. He found that the wire so treated resisted rusting longer than ordinary wire,|| and he has even proposed to put potassium bichromate into steam boilers to prevent or check corrosion. Soon after reading his paper I made some experiments in the laboratory, and found that the addition of bichromate to a concentrated water drawn from a boiler, in proportions ranging from 10 to 100 grains per gallon, did not prevent the corrosion of steel, especially when in metallic contact with copper, as in a locomotive boiler; in fact, in some of the experiments serious local pitting resulted, and I came to the conclusion that it would be dangerous to put bichromate at anyrate into locomotive boilers. This subject has been more recently and completely investigated by Friend and Brown*, who have shown that potassium bichromate, instead of being protective, may become actually corrosive in the presence of other salts, owing to the liberation of acids which tend to destroy the passivity produced by chromic acid. In the presence of other electrolytes much better results are obtained with neutral potassium chromate than with bichromate, but the quantity required to produce a tangible result is considerable.

One is led to enquire why the corrosive effect of dilute solutions should be lessened as the strength increases. The answer appears to be that the lessened corrosion is due to the diminished solubility of oxygen, confirming what has been known about salt solution for 70 years. Adie, in 1845, read a paper before the Institute of Civil Engineers, in which he showed that wrought iron in 80 days lost 19 times as much by corrosion in fresh water as in saturated common salt solution, and cast iron four times as much. Friend has recently shown, in fact, that in the entire absence of air, salt solutions have no action whatever upon iron. Sea water, nevertheless, is corrosive at ordinary temperature even in the absence of air, owing to the magnesium chloride present. In marine boilers, however, a certain amount of sea water is found beneficial. Rowan, in 1876, quoted the case of a steamer whose boilers were worked with a minimum proportion of sea water, and in 12 months were so badly corroded that a new set were required. In the new boilers the proportion of sea water was considerably increased, and the life of the boilers greatly prolonged in consequence. It is evidently, therefore, of the greatest importance to exclude air from boilers as much as possible, and to take care, especially in using condensed water, that air is not pumped in with the feed. Stromeyer† states that corrosion of marine boilers using condensed water has been very materially reduced by the introduction of slow-running pumps, which do not require air for their smooth working, and which cease running when there is no water supply. The air *dissolved* in natural soft waters must of necessity be introduced with the feed. Attempts have been made to extract this air by passing the water through a vacuum chamber, but with no very marked success. Beneficial results have, however, resulted from the presence in the feed of organic matters which combine with the dissolved oxygen, such as tannin. No doubt the beneficial effects of sodium arsenite in preventing corrosion are due to the same cause.

Although the systematic researches of Prof. Heyn and Dr. Friend, to which I have referred, have thrown very valuable light upon the corrosive effects of salts in solution, much more work needs to be done, especially at higher temperatures, and under conditions such as obtain in steam boilers. Most of the researches have been made at temperatures no higher than 200° Fah., and in solutions freely exposed to air and light. If corrosion took place in steam boilers to the extent shown possible by some of these experiments, the lives of boilers would be measured by weeks or months instead of years. We know that temperature influences the results vastly, especially by reducing the solubility of gases, and also that corrosion is much less active in the dark than in daylight.

Another cause of active corrosion to which I must not omit reference is the presence in the water of fatty acids. Corrosion from this cause has become less frequent since the introduction of mineral oils as lubricants, but in the days when animal fats, such as tallow, were commonly used in cylinders, and even put directly into boilers, such cases were common. Animal and vegetable oils are compound bodies which, when heated with steam, split up into fatty acids and glycerine. The fatty acids thus set free are very corrosive to iron and many other metals. Oleic acid from olive oil, if heated in a test tube with water and iron filings, attacks the iron vigorously, forming brown ferrous oleate and evolving hydrogen gas. The ferrous oleate is decomposed, by oxidation, into ferric hydroxide and free oleic acid, which again attacks more iron, and in this way quite a small quantity of free fatty acid has been known to perforate wrought-iron plate more

* Analyst, 30 (1905) 225.

† Mitteilungen, 26 (1908) 1.

‡ *Loc. cit.* 28 (1910) 62.

§ "Journal Iron and Steel Institute," 1911 (1), 125.

|| Brereton Baker (Chem. Soc. Annual Reports, 7 (1910) 38) states that all attempts made by him to make iron passive to ordinary water by treatment with dilute chromic acid have been unsuccessful, and this agrees with my own observations.

* *Loc. cit.*

† Annual Report to the Manchester Steam Users' Assoc., 1909.

than ½in. in thickness. Pitting and corrosion along the bottom of steam boilers may result from this cause, and also at the flanges and screwed joints of water pipes when red lead and linseed oil are used to make the joints. The danger of allowing grease of any kind to obtain entrance to steam boilers is now too well known to need insisting upon. In screwing the stays, fittings, and wash-out plugs into boilers, pure mineral lubricants should be used exclusively, and all surplus oil should be removed from new boilers by thorough digestion under pressure with hot soda solution and washing out with clean hot water before putting the boilers into use.

It is a well-known fact that neither iron nor steel are homogeneous metals. If the polished and etched surface of a piece of wrought iron be highly magnified it is seen to be composed of polygonal crystals of iron and particles of slag, and if you look at an etched specimen of wrought iron you will see that it is built up of layers of iron, between which the layers of slag are sandwiched. When medium carbon steel is similarly magnified it is seen to have a still more complex structure, composed of areas of iron containing in solution more or less manganese, phosphorus, and silicon, darker areas of carbide of iron occurring in the complex which we call pearlite, sulphur existing as isolated particles of sulphide of manganese and frequently particles of slag. These different constituents are not uniformly mingled together, but present a variety of structures depending upon the heat treatment and kind of work the steel has undergone. The pearlite, for instance, is not always laminated. In hardened steels it is more or less completely emulsified, and in hardened steels granular. According to a recent report of the B.A. Committee, which is investigating the corrosion of carbon steels, the state of division of the carbon has a great influence on the rate of corrosion in sea water, the hardened steels corroding more rapidly than the unhardened or tempered steels. The different varieties of pearlite also differ in polarity. Moreover, the impurities in the molten steel have a tendency to segregate during solidification, sometimes so seriously that drillings taken from different parts of the finished material may have a quite different chemical composition. Areas of different electrical polarity are thus formed, between which action readily occurs, stimulating corrosion. Owing to the ingenuity of Drs. Cushman and Walker we have been put into possession of a chemical reagent, to which they have given the name of "ferroxyl," which shows this in a very beautiful manner. It is a jelly containing in solution phenolphthalein and potassium ferricyanide. The phenolphthalein gives a pink colour in the presence of hydroxyl ions and the ferricyanide gives a deep blue precipitate in the presence of soluble ferrous iron. The jelly merely serves to localise these effects and prevent them from running into one another. If a piece of iron or steel is placed in the melted jelly and the jelly allowed to set, there are developed on the surface of the metal pink areas and blue areas indicating the positions of nodes of opposite polarity. The blue colour shows the anodic areas where iron is going into solution, the pink colour shows the cathodic areas where no iron is being dissolved. It is thus possible to demonstrate in a simple and convincing manner a fact which throws a flood of light on one cause of localised corrosion or pitting, especially in boilers. The ferroxyl indicator may be used to demonstrate:—

(1) Nodes in a piece of steel boiler plate (scale removed).

(2) Nodes in wrought iron (scale removed by sandblasting).

(3) Nodes in exceptionally pure boiler-tube steel.

(4) Boiler plate partially protected by mill-scale (where the scale has been removed the iron is corroding, as shown by the blue spots).

(5) Cast iron.

(6) Tin plate (where the tin has been removed the iron is corroding).

(7) Galvanised iron (complete protection).

(8) Wrought-iron nails corroding where the iron is not protected by the mill scale.

(9) Electrolytic iron.

(10) Steel riveted to copper.

(11) Steel riveted to brass.

(12) Steel rods passivified by bichromatic solution containing respectively oil 1 per cent., 5 per cent. and 10 per cent. of bichromate, also an untreated rod.

We learn from the ferroxyl indicator the great importance of obtaining for such purposes as steam boiler construction iron and steel as homogeneous as possible, and it would be worth while to pay a high price for such material. As Cobb* has stated in a recent paper, the presence of an impurity in iron determines so many corrosion centres, and its influence depends more on quality and distribution than on quantity; a more homogeneous iron, even if chemically less pure than another, may, therefore, be more highly resistant to corrosion. The same difference of electrical polarity as is found between different areas of the same piece of iron exists between different pieces, every piece tested showing electrical effects with every other. Not only, therefore, is homogeneity of composition important in each individual part of a structure exposed to corrosive influences, but the different parts should be as much alike as possible.

Owing to the extreme difficulty of preventing segregation of the impurities in iron and steel and of producing a perfectly homogeneous material, the less impurities the better. Unfortunately, the nearer a commercial iron or steel approaches purity the more difficult it is to produce it in a thoroughly deoxidised and degasified condition. Cushman states, however, that there is now being made in the United States in several rolling mills an extremely pure ingot iron containng less than 0·05 per cent. of total impurities. He gives the analysis as:—

Iron	99·95
Carbon	·026
Phosphorus	·004
Sulphur	·019
	99·999

This, he says, is no chemical curiosity, but is manufactured in basic open-hearth 50-ton converters. As showing how much more resistant such iron is to the action of sulphuric acid than ordinary iron and steel, Friend quotes the following results from a pamphlet issued by the American Rolling Mill Company. Small plates of this iron, of ordinary steel, and of charcoal iron were polished, weighed, and completely immersed in dilute sulphuric acid of 25 per cent. strength at 110° C. for 1½ hours. The steel lost in weight 87·5 per cent. and the charcoal iron 52·1 per cent., but the ingot iron lost only 2·16 per cent. If metal so free from manganese can be depended upon to be free from oxygen and thoroughly reliable mechanically, a great field of usefulness lies before it. Several patents have been taken out by the International Metal Products Company, of Newark and Middleton, U.S.A., for ingot iron made by the basic process and deoxidised with aluminium, the object stated being to obtain an iron of at least 99·80 per cent. purity, containing not more than 0·04 per cent. of either carbon or manganese, not more than 0·10 per cent. of carbon, manganese, silicon, sulphur, and phosphorus together, and not more than 0·04 per cent. of oxygen. The metal is stated to possess a very high degree of malleability and ductility and to be very resistant to corrosion. This pure iron is well worth the attention of engineers. One of the most injurious impurities in steel is sulphur and one of the most active in causing corrosion. In all well-made steel the sulphur exists as manganese sulphide, disseminated throughout the metal in the form of more or less minute particles which can readily be seen when a polished section is examined under the microscope. These form active corrosion centres, which are not electrolytic, but lead to the formation of sulphuric acid by oxidation, which attacks the iron. An interesting example has been given by Huntley†. Serious pitting had started in a stand-by boiler at the generating station of the London Electricity Supply Corporation, which caustic soda was found powerless to stop. On examining the boilers, numerous blisters were seen, varying in size up to 30 mm. diam., the bulk of them being just below the water level. On pricking the blisters, each was found to contain a liquid with a fine black powder in suspension, and a pit was seen to be forming in the centre of each blister. Analysis showed that the liquid was a solution of ferrous sulphate containing free sulphuric acid, although the water in the boiler was alkaline and contained much less sulphur than the liquid in the blisters. The pitting

* Journal Iron and Steel Institute, 1911 (1), 170.

† Jour. Soc. Chem. Ind., 28 (1909), 339.

was traced to the sulphide of manganese in the steel, which by oxidation gave rise to free sulphuric acid which attacked the iron, forming ferrous sulphate. This being oxidised to ferric sulphate by the oxygen in the water would attack more iron, and in the quiescent water of the stand-by boiler the oxides precipitated by the alkali in the water would not be washed away, but would seal in the corrosive liquid with a semi-permeable membrane through which the oxygen of the water could pass but not the caustic soda. The use of sodium arsenite instead of caustic soda completely stopped the trouble, the arsenite presumably using up the oxygen in the water.

The influence of strain on corrosion must be mentioned. It is a subject on which the late Thomas Andrews worked for many years, and his results are to be found in papers communicated to the Institute of Civil Engineers. He found that strain always causes a difference of potential, and the use of strained material should, therefore, be avoided where corrosion is likely to be set up by it. To this Friend attributes the unusual tendency to corrosion shown by indentations and abrasions on the surfaces of boilers. Stromeyer suggests that grooving may also arise from this cause, "those portions of the boiler which are most severely strained being attacked by the salts in the boiler water, and as these regions get thinner, and especially if the reductions are of the nature of thin lines or grooves, the local stress increases and with it the corrosive action." He suggests that if this be the true explanation the action would proceed most rapidly where the concentration of the salts is greatest, and mentions a curious confirmation of this which was afforded by the failures of some caustic soda evaporators. Where the strains were severe, and only in these places, rivet heads flew off on the caustic side and tubes cracked where they had been enlarged by the expander. The experiment was then tried of turning several pairs of mild steel rings, shrinking one of each pair into the other, and then exposing them in a caustic evaporator for several months. On removing the rings, cutting them up and bending them, those which had been subjected to a tension stress were found to be quite brittle, but those exposed to a compression stress were perfectly ductile.

The action reminds one of the brittleness which may be caused by acid corrosion. Railway engineers are familiar with the fact that the springs of wagons which have carried acid materials, such as nitre cake, are frequently found broken as the result of corrosion by the acid liquid which drains from such material when loaded wet or seriously wetted by rain in transit. This effect is due to the occlusion of hydrogen which is given off by the action of the acid on the metal, thus: $Fe + H_2SO_4 = FeSO_4 + H_2$. It has been shown that iron wire immersed in dilute sulphuric acid can absorb 20 times its volume of hydrogen, which becomes condensed in the pores of the metal. The brittleness is only a temporary feature, as the hydrogen is slowly given off again on exposing the wire to the air at ordinary temperature, and rapidly by annealing at a red heat, and the metal, if not left in the acid for too long, regains its normal properties. Longmuir found that even stoving overnight at 100° C. to 150° C. was sufficient to eliminate the absorbed oxygen from steel rods ⅜in. diam. He has made the rather remarkable suggestion that the corrosion of steel rails in tunnels, which is the result of slow attack by very dilute acid, may in the course of a few years develop brittleness of the rails corresponding to that of a more rapid attack by stronger acid.

To sum up what has been said about corrosion of steam boilers we see that the causes which may lead to internal corrosion are very numerous and include:—

(1) The corrosive action of dissolved gases and salts in the feed-water.

(2) Segregation of impurities and general want of homogeneity in the metal of the boiler plates.

(3) Sulphide of manganese in the steel.

(4) Local galvanic acid due to strain in the metal.

(5) Galvanic action due to the use of dissimilar metals in construction, leading to local corrosion, as of the iron stays in metallic contact with the copper firebox plates of locomotive boilers.

The remedies are:—

(1) Exclusion of air as much as possible.

(2) Avoidance of a weak alkaline condition of the feed-water and of excessive concentration, especially in presence of alkaline chlorides, sulphates, and nitrates.

(3) The use in construction of steel of high quality, with especially reference to freedom from sulphur and homogeneity of composition.

(4) Avoidance of strained metal and of anything which may lead to the setting up of local strains.

The mill scale or skin of the iron, where it remains, must exert a considerable influence on corrosion. If it were intact all over the interior of the shell, it would be a valuable protection, but in bending the barrel plates the greater part of the scale shells off, remaining attached only in places, and here pitting is promoted. The only remedy for this would be the entire removal of the scale. Tank plates are treated in this way by the Admiralty by pickling in acid, but one would hesitate to recommend treating boiler plates in this manner for fear of rendering them brittle.

The interesting subject of ferro-concrete I can only touch upon in the very briefest manner. So long as the iron or steel is completely encased in a compact mass of good cement-concrete, preservation is perfect. Slight porosity is not harmful, provided the cement contains a sufficiently small excess of free lime. But even the slightest electrolytic action is highly dangerous, and, therefore, the greatest care must be taken to shield the metal from stray electrical currents from power stations and tramways.*

In bringing these remarks to a conclusion, I am aware that I have laid myself open to the charge of having dealt very imperfectly with many branches of a very complex subject, any one of which would have sufficed for a single evening. But I know that your interests are diversified, and I hoped that by covering a wide ground I should appeal to a larger number and thereby promote a better discussion.

SULZER'S ENGINE GOVERNORS.

Messrs. Sulzer Bros., of Winterthur, have recently designed and patented several arrangements of engine governors of the drum type in which the valve gear is actuated by means of an independent small motor controlled by the governor. In the accompanying illustrations, Fig. 1 shows a drum governor with an auxiliary motor of the piston type. Fig. 2 is a plan on a smaller scale showing the general arrangement of the device seen in Fig. 1. Fig. 3 shows a construction and arrangement for controlling the speed by hand, the device being fixed to a convenient part of the engine frame; and Fig. 4 shows a similar construction combined with an apparatus for controlling the speed by hand and also by means of an electromagnet from a distance.

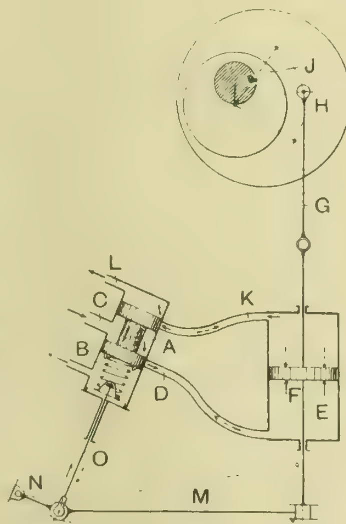


Fig. 1.—Sulzer's Engine Governor.

In the arrangement shown in Figs. 1 and 2, the weight A is designed as a piston valve, the movement of which is controlled by the centrifugal force. If the speed of the shaft carrying the drum governor exceeds a predetermined limit, the weight A will be moved outwards by the centrifugal force in opposition to the action of a coiled spring B, the strength of which is adjusted in accordance with the desired normal engine speed. In this manner a port D is uncovered and communication established between the supply conduit C and the conduit D, through which liquid under pressure—for instance, oil—then flows. The liquid passes in the direction of the arrows shown in full lines through the conduits C and D into the cylinder E of the auxiliary or independent small motor, the piston F of which is thus forced upwards. The piston F is provided with a rod G, pivoted at H to the outer eccentric J, and, in this way, when the piston rises, the cut-off of the main engine will be altered. The oil above

* Knudson (J. Franklin Inst. 168 (1909), 132) has shown how exceedingly difficult this shielding becomes where the earth is used as a return, and the only way of avoiding access of stray currents with certainty is to use a non-grounded return.

the piston F in the auxiliary motor passes through a conduit K and return pipe L to the reservoir. To return the piston valve A to its central position while the cut-off is being altered, the piston F of the auxiliary motor is connected to a lever M pivoted at N and connected to a rod O attached to the supporting cap of the coiled spring B. In this way, the piston F moves upwards and the spring B is additionally compressed to return the piston valve A to the neutral position, when the ports D and K are closed once more. When the speed of the main engine falls below a predetermined limit, the piston valve A is moved inwards by the action of the coiled spring B, and the liquid will then flow from the underside of the piston F in the direction of the arrows shown in dotted lines, the action being the reverse of that already described.

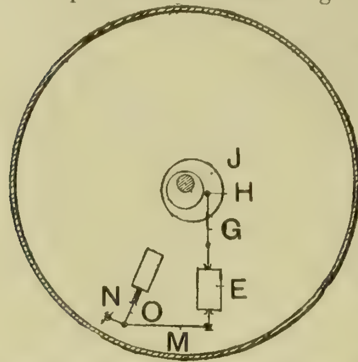


FIG. 2.—SULZER'S ENGINE GOVERNOR.

The apparatus shown in Fig. 3 illustrates an arrangement in which the centrifugal mass, as before, forms a slide valve for the auxiliary motor A. In this case the auxiliary motor is of the rotary type, having piston blades which, together with fixed divisions, form four chambers, C, D, E, and F. The centrifugal mass G, *i.e.*, the piston valve of the auxiliary motor, controls the flow of oil under pressure from H through the valve chamber J, either through a pipe into the chambers C and E or through a pipe into the chambers F and D of the auxiliary motor. The liquid under pressure from the chambers which are not in communication with the valve chamber escape through a pipe B or K, as the case may be. A lever L connected to the piston blade transmits the movement of the latter to a rod M, whereby the outer eccentric N is turned relatively to the inner eccentric, thus altering the cut-off. A lever P connected to the rod M and pivoted at O depresses or releases the spiral spring R, and thus ensures the piston valve G returning to the neutral position.

In the arrangement shown in Fig. 3 the centrifugal force acting on the mass of the piston valve G is counteracted partly by the spring R and by liquid under pressure admitted

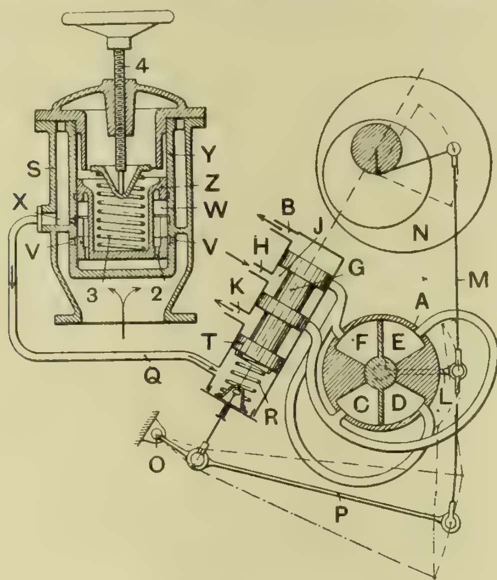


FIG. 3.—SULZER'S ENGINE GOVERNOR.

through a pipe Q to the under side of a piston T connected to the piston valve G. By adjusting the spindle 4, the pressure under the piston T can be regulated, and in that way the valve G may be moved from its neutral position, which results in a change in the speed of the engine. In this construction variation in the pressure of oil admitted through the pipe Q is effected by means of a reducing device S, to which oil under pressure is admitted. The oil passes through openings V into a chamber W, and thence through openings X into the pipe Q. In the casing Y is arranged a piston valve Z provided with openings 2, through which the oil under pressure passes to its under side, thus maintaining the piston valve Z in the position of equilibrium with the spring 3. There is always a certain continuous flow of liquid past the throttling ports owing to the unavoidable leakages in the whole system. The valve Z throttles in proportion as the spring 3 is compressed by a hand-actuated screw 4. The degree of throttling, and consequently the oil pressure under the piston T can therefore be adjusted at will by means of a spindle 4, and in that way the speed can be altered. The throttling device is in all cases stationary, and connected to the revolving part of the governor by glands and piping Q. In this way the speed of the engine may be controlled from any desired point.

Fig. 4 shows a speed-adjusting device in which the hand-operated spindle 4 shown in Fig. 3 is actuated by a small oil motor. The admission of oil to this motor is controlled by electromagnets, so that the speed of the engine can be altered either by hand or electrically from any desired point, for instance, from the switchboard. Referring to Fig. 4, if the speed is to be increased a circuit from some source of electricity B is closed at some point—for instance, at A, so that a magnet D is excited by the winding C. In this way a lever which forms an armature E is attracted, the horizontal arm of this lever being connected to a piston valve F. This arm carries a counterweight which balances the piston.

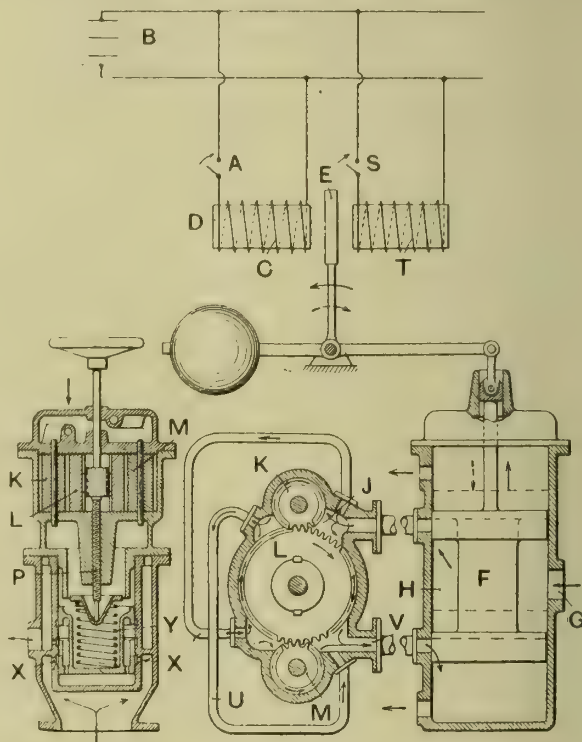


FIG. 4.—SULZER'S ENGINE GOVERNOR.

When the electromagnet D is excited the piston valve F is moved upwards into the position shown by dotted lines, which enables liquid—for instance, oil—under pressure to pass through a port G into the valve chamber H, and thence into the interior J of a rotary servomotor of the toothed-wheel type, the oil driving the toothed wheels K, L, and M. The oil leaves the rotary motor in the direction of the arrows through the pipes U and V. The spindle P of the throttling device engages with a toothed wheel L by means of a feather key, and this spindle controls the tension of the spring Y. If the speed of the engine is to be reduced, a contact such as S in the electric circuit is closed, the electromagnet T being thus excited so that the armature E is attracted to the right, with the result that the piston F sinks. The flow of oil through the rotary motor then takes place in the opposite direction, and the tension of the spring Y is reduced so that the supply of oil under pressure through the openings X is throttled. This oil gear motor is mounted above a reducing valve of precisely similar design and performance as that already described and illustrated in Fig. 3. At the same time the hand wheel at the end of the spindle P permits of a manual adjustment if it is desired to control the speed of the engine in this manner.

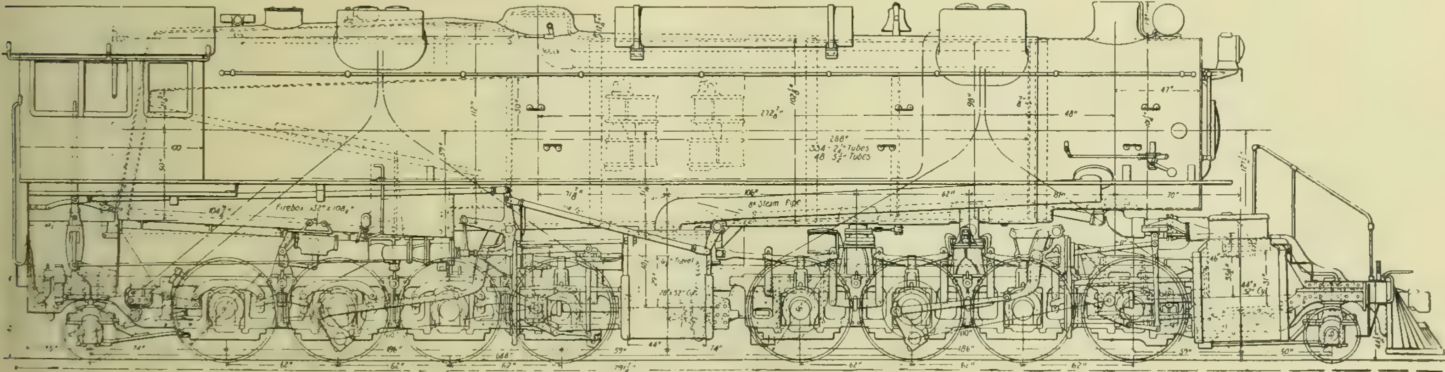
A POWERFUL MALLET COMPOUND LOCOMOTIVE.

THERE has recently been constructed by the American Locomotive Company, for use on the Virginian Railway, four powerful Mallet compound locomotives, each of which is capable of exerting a tractive power of 115,000lbs. This enormous tractive power is obtained with less than 60,000lbs. average weight per driving axle. These locomotives, which are described and illustrated in "The Railway and Engineering Review," of June 22nd, were designed to meet the particular difficult service on a section of this railway without exceeding the existing limitations on axle loads. Apart from the enormous weight and power of the locomotive as a whole, the dimensions of some of the principal parts are impressive, as showing the extent to which all limits were exceeded in the design and construction. The following warrant special attention:—

Outside diam. of boiler at front end	100in.
Outside diam. of largest ring	112in.
Tubes, number and diam.	344; 2¼in.
Flues, number and diam.	48; 5½in.
Heating surface, total	6,760 sq. ft.
Superheating surface	1,310 sq. ft.
Firebox, size	184½in. by 119in.
Total length of boiler	50ft. 1⅛in.
Low-pressure cylinders	44in. by 32in.
High-pressure cylinders	28in. by 32in.
Tender, water capacity	12,000 galls.
Tender, coal capacity	15 tons.

The design, as far as running gear is concerned, represents the builders' ordinary practice. Several new features, however, are introduced in the design and construction of the boiler, one of the most interesting of these being the arrangement of the firebrick arch employed. This consists of a combination of the "Security" and the Gaine's arches. With this arrangement, it is claimed, complete deflection of the gases is secured, whereby better combustion is obtained and the back end of the firebox more fully utilised, with a resulting increase in the generation of steam. In addition, this arrangement gives an increased firebox volume, which is one of the features peculiar to the Gaine's arch and which also tends to improve combustion. The grate area is 99 sq. ft., the grates being on the shaking system, power operated, and composed of six sections, so arranged that any one section can be operated alone if desired. The engines are equipped with superheaters of the firetube, double-loop type. The principal features of these locomotives are indicated in the following table:—

Type	2-8-8-2
Service	Pusher
Cylinders	28in. and 44in. by 32in.
Valves	
Valves	High pressure, piston; low pressure, double ported slide.
Tractive power	115,000lbs.
Boiler, type	Conical connection.
Min. diam.	100in.
Working pressure	200lbs.
Firebox, size	109in. by 174in.
Grate area	99·2 sq. ft.
Kind of fuel	Soft coal
Tubes, number	48 and 334
Diam.	5½in. and 2¼in.
Length	24ft.
Heating surface, firebox	410 sq. ft.
Tubes	6,350 sq. ft.
Superheater	1,310 sq. ft.
Total	6,760 sq. ft.
Driving wheels, diam.	56in.
Journals	6½in. by 13in.
Truck wheels, diam., front	30in.
Journals	6½in. by 13in.
Back diam.	30in.
Journals	6½in. by 13in.
Weight, on driving wheels	479,000lbs.
Total engine	540,000lbs.
Total engine and tender	752,000lbs.
Wheelbase, driving	42ft. 1in.
Total engine	57ft. 4in.
Total engine and tender	
Tender, wheels, diam.	33in.
Journals	6in. by 11in.
Capacity, water	12,000 galls.
Capacity, coal	15 tons.



A LARGE MALLET COMPOUND LOCOMOTIVE.

MECHANICAL STOKERS ON LOCOMOTIVES.

THE rapid development in size of American locomotives that has taken place during recent years has directed attention to the desirability, in view of the arduous task of stoking these monsters by hand, of applying mechanical stokers, and a number of these have been developed and subjected to practical tests. A description of the principal types of stokers in use on American railroads, and the results obtained with them were given in a report of a committee presented at the recent annual convention of the American Master Mechanics' Association, an abstract of which follows.

Last year the committee expressed the expectation that this year, judging from the progress which was being made in the development of the mechanical stoker, it would be able to report finally on a few stokers which had then been developed sufficiently to render practically uninterrupted service. The committee also pointed out that the principal benefit to be derived from the utilisation of a perfected stoker fulfilling the requirements specified was the realisation of the maximum boiler capacity of locomotives with the ultimate result of increasing their hauling capacity and reducing their cost of operation per ton mile of service rendered. The actual service performance of two stokers complying with the specifications laid down in last year's report, as developed by extensive enquiry among railroads who have heeded your committee's request by lending their aid and installing a limited number upon large locomotives prompted the committee in reporting that these two stokers have, in a measure, fulfilled its expectations, inasmuch as the indications are that their service has been sufficiently reliable in practical operation on a large number of heavy locomotives. These stokers are the Crawford and the Street.* Both types of stokers in successful service to-day maintain the same general principles in design originally employed. The improvements

* For illustrations and detailed particulars of these stokers see the "Mechanical Engineer," April 21st and June 30th, 1911, pp. 485 and 808, Vol. XXVII.

made on them, which resulted in making their operation practicable, are improvements of detail only, such as would result from the knowledge gained of the weaknesses of individual details brought out by actual service.

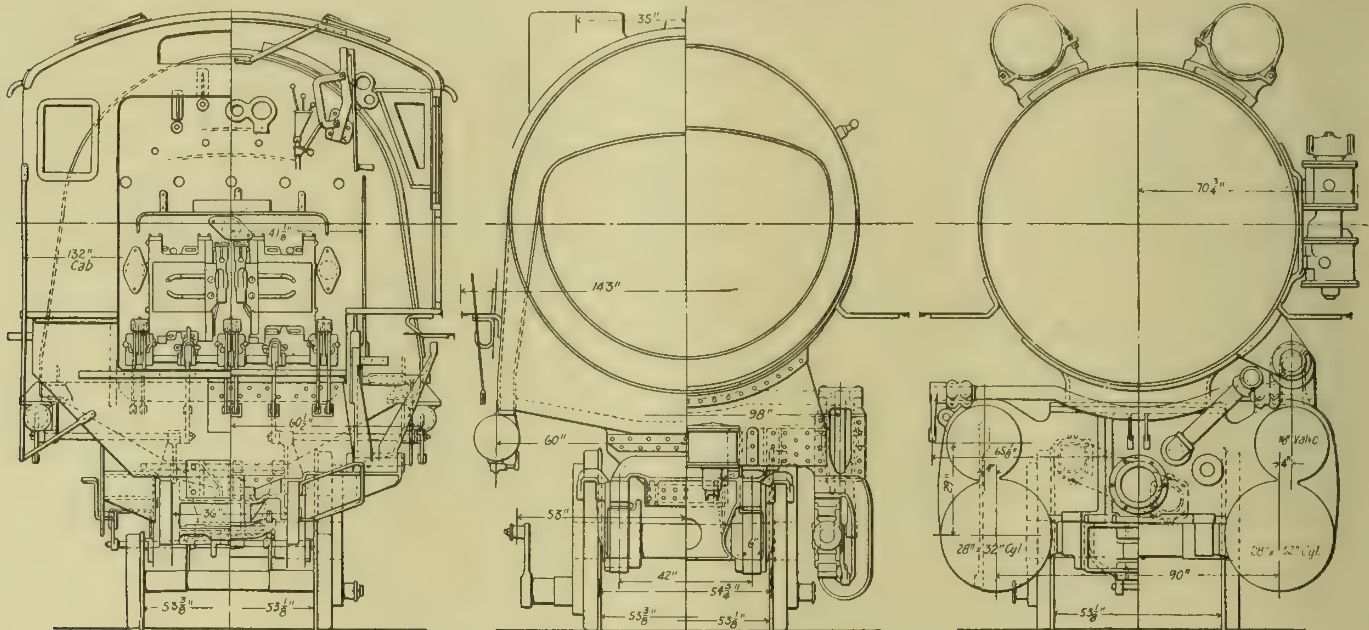
The principal benefit to be secured by the application of the mechanical stoker to large locomotives is the realisation of the maximum boiler capacity. When three or four years ago the necessity for passenger locomotives and freight locomotives of still greater capacity than those already in service became apparent, they were not generally considered possible without some device to assist in handling the increased quantity of fuel which it was thought these engines would require. The solution of the apparent difficulty, however, was accomplished to a large extent by providing means which reduced the actual fuel requirements of large locomotives. These means are the superheater, the brick arch, improved boiler, better engine proportions, more scientific methods of firing, and better locomotive maintenance. The fact is being more strikingly realised every day that a 5 per cent. saving in fuel amply warrants the installation of apparatus and the adoption of means which may result in a 5 per cent. increase in the cost of maintaining motive power.

The net effect of these means as far as the stoker is concerned, in spite of the fact that they tend to increase maintenance expenses, has been to defer, to some extent, the absolute necessity of the stoker as a means on present-day engines to get out of them their maximum capacity. It should not be inferred, however, from this statement that the mechanical stoker does not find application to certain engines in operation to-day, especially of the larger Mallet types which are in continuous service on long mountain grades. On the other hand, too, as the greater sustained tractive efforts of the large engine equipped with superheaters and brick arches is gradually taken advantage of, its fuel consumption per hour will increase, though decreasing on the ton-mile basis, with the eventual result of possibly making necessary to some extent means, in addition to those already provided, to supply fuel to the engine up to its maximum requirements.

When this condition develops, as it is bound to, by traffic increases, careful investigation of tonnage ratings, and the raising to a higher standard the efficiency of operation, the demand for a perfected type of mechanical stoker will become more acute than ever. It is, perhaps, somewhat of a good fortune that the superheater has stepped in and tided over the difficulty that would have resulted while the stoker was in process of development and the demand for large engines becoming more insistent. A brief description of the stokers now in use and under process of development is given herewith:—

The Crawford Underfeed Stoker.—This stoker, in service on the Pennsylvania and the Baltimore and Ohio railroads, has been developed into a practical operating machine, and is being applied to all of the large Pacific passenger locomotives and the consolidation freight locomotives building for the Pennsylvania lines west of Pittsburg. On these lines 45 locomotives are now equipped, and 20 locomotives under construction are being equipped. The lines east have ten locomotives equipped. The Baltimore and Ohio R. R. reports one Crawford stoker in service on a Mallet engine with a grate area of 100 sq. ft., and a tractive power of 105,000lbs., working compound.

The 45 locomotives on the Pennsylvania lines west which include some of the earlier designs, have made a total of 7,361 trips up to the middle of March, of which 3,640 were 100 per cent. stoker fired, 2,082 between 75 and 100 per cent., and 1,639 below 70 per cent. The per cent. stoker fired is in reference to the amount of coal put into the firebox by the stoker; as, for instance, a 90 per cent. stoker fired trip means that the stoker fired 90 per cent. of the coal while 10 per cent. was hand fired, the firing by hand being done to fill up spots in the grates which resulted from imperfect distribution of the coal by the stoker. Some capacity tests on the Western division of the lines west were run with a dynamometer car on various passenger locomotives, one of which was a Pacific type equipped with a Crawford stoker. The results of these tests have not been completed so as to become available for this report, but the preliminary figures indicated, with respect to the coal consumption, that the stoker made as good a performance as the skilled fireman selected for the hand-fired locomotives.



A Large Mallet Compound Locomotive. Cross-sections.

The Crawford stoker applied to the Mallet engine of the Baltimore and Ohio R. R. has been in service about a year. Some difficulty was experienced with this stoker due to the fact that some departures in design were made from the stoker as originally developed, consisting principally in the provision of two cylinders to operate the plungers instead of one. This necessarily added certain complications which subsequently gave trouble. After certain changes, the stoker gave a fair distribution of coal. This stoker is still in service but has not given quite the satisfactory performance so that it could be termed unqualifiedly successful. Inasmuch as this particular stoker is a modification of the Crawford stoker as now perfected for engines of the type to which it has been applied on the Pennsylvania lines, some difficulty, as experienced with it, might reasonably be expected.

The Street Overfeed Stoker.—This stoker is now being built in two somewhat different forms, distinguished from one another as the screw conveyor type and the crusher type. The screw conveyor stoker is built to take screened coal from the tank and distribute it evenly over the grates in the firebox without being handled by the fireman. The coal used by this machine must be passed through a screen having 2in. square mesh before it is placed on the

tank. With this type of machine the fireman has no manual labour to perform excepting that of raking the coal on top of the screw conveyor when the supply in the tank is low.

The crusher stoker is designed to take lump, run-of-mine, or slack coal from the tank and distribute it over the grates in the firebox. With this type of machine, all the coal must be scraped or shovelled into the crusher by the fireman. The parts of the stoker on the back boiler head and the distribution systems are the same with both machines. The primary difference between them is in the means provided for conveying the coal from the tender to the distribution system, the screw conveyor type only needing one engine to operate the entire machine, whereas the crusher type needs two; one for the crusher, the other for the conveying mechanism.

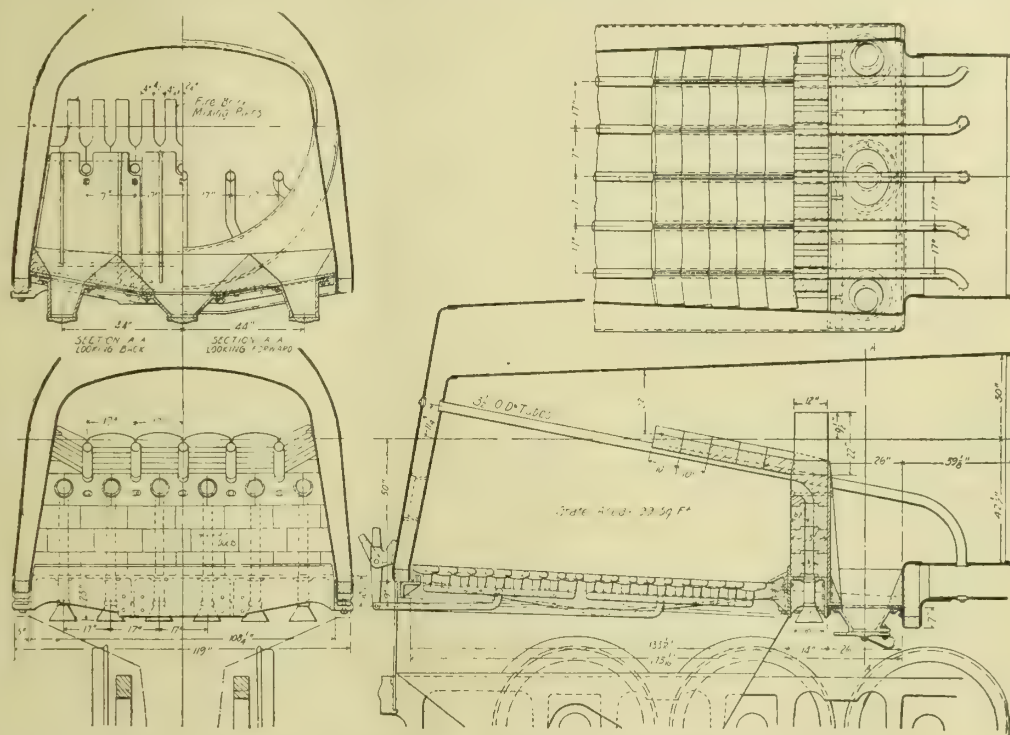
It is the opinion of the designer of the Street stoker that the provision of means for preparing coal on the tender for suitable firing is but a temporary expedient to be used with experimental machines, and that for practical operation of a large number of stokers, it would be more feasible to prepare the coal at the chutes suitable for stoker firing before delivery to the tender. The committee last year recommended that a stoker, in order to be complete, should be able to handle run-of-mine coal. In this respect the Street screw conveyor type of stoker does not meet the committee's recommendations. The indications, however, are, judging from recent developments, that it will be more economical to concentrate the means for properly preparing coal for stoker consumption at the coal chute with the net gain reducing to a minimum the complication of a machine which, when applied to a locomotive, will of necessity add to the expense of locomotive maintenance and the likelihood of engine failure.

The total number of Street stokers applied and in service today are 30, 13 of which are of the crusher type and 17 of which are of the screw conveyor type. Sixty-nine stokers of the screw conveyor type are under construction for application to 45 Mallet engines ranging in tractive power from 72,800lbs. and 99·5 sq. ft. grate area to 105,000 lbs. tractive power and 100 sq. ft. grate area, and 24 Mikado engines of 60,800lbs. tractive power and 66·7 sq. ft. grate area. The 30 stokers in operation are applied to engines ranging in size and type from 45,700lbs. tractive power consolidation freight, 58,000lbs. tractive power mountain passenger, and 60,700lbs. tractive power Mikado freight to 105,000lbs. tractive power Mallet freight and pusher engines. At the last convention of this association, eight of these stokers were in operation. From the service rendered by them, as well as the results of individual investigations made by various roads, the number has grown to 30, with 69 under construction for entry into service within the next few months.

General enquiry of different roads which have the latest type of Street stoker in service has developed the facts that its service is satisfactory, as indeed is attested to by the locomotive boiler; that it permits of carrying a thinner fire than ordinarily possible with hand-firing; that with considerate attention, it renders practically uninterrupted service; but that it does not necessarily effect economies in fuel consumption. The fact was also developed that the greatest trouble in the operation of this stoker results from the unfamiliarity of engine crews with it at the time of introduction. It takes considerable drilling to get a sufficient number of men on a division trained so that the stoker may be handled successfully in pool service. This difficulty, however, is a minor one, and naturally follows at the outset of the use of a device new in railroad service. As the stoker becomes more generally utilised, this trouble will disappear.

The Hanna Overfeed Stoker.*—This stoker, as far as developed, was briefly reviewed in the proceedings of the Master Mechanics' Association for 1911. As a coal-distributing means, the Hanna stoker has successfully demonstrated its possibilities. It has been in continued service on engines of the consolidation, Pacific and Mallet types, giving a good account of itself, particularly when the engine crews took a personal interest in its operation. The manufacturers of the Hanna stoker are revising its design and construction so as to increase the scope of their apparatus to comply with the specifications as laid down by your committee.

The Barnum Underfeed Stoker.—This stoker as developed so far by the Chicago, Burlington and Quincy R. R. employs screw conveyors located in troughs extending longitudinally just below the grates. The screw conveyors decrease in diameter from the rear of the firebox to the front. Above the conveyors in each trough are a series of inclined plates, adjustable for height and inclination. The clearance between the conveyor and the bottom of the trough may also be adjusted to secure the best results. The conveyors are operated by a transverse worm shaft under the cab deck which is rotated by two small steam engines secured on the outside of the frames. A coal crusher on the latest type of stoker as applied to five 2-10-2 type engines recently built for the Chicago, Burlington, and Quincy R. R. is also provided. This crusher is driven by a small steam engine located on the tender. It delivers coal to a belt conveyor which transfers it to a transverse trough from which it is discharged into the longitudinal feed troughs. In addition to the five 2-10-2 type engines equipped above, the Barnum stoker has been in service on a switch engine of the Burlington road operating in Chicago, as well as a prairie type engine operating in freight service. It is reported as giving good results with both low grade bituminous coal and lignite. It is further reported that indications at this time for this stoker are that it is a practical machine, assisting in making steam readily and being free from failures and breakdowns.



A LARGE MALLET COMPOUND LOCOMOTIVE. SECTION OF FIREBOX SHOWING ARRANGEMENT OF SECURITY (GAINES') BRICK ARCHES.

The Dickinson Overfeed Stoker.—This stoker was tried out on the Erie Railroad. It employed the fundamental principle of coal distribution of the Hayden stoker further developed. It was equipped with a coal crusher and means for conveying coal, consisting of a screw conveyor transmitting the crushed coal to a bucket conveyor encased in a housing, which bucket conveyor in turn delivered the coal

* This stoker was illustrated and described in the "Mechanical Engineer," May 5th, 1911. See page 551, Vol. XXVII.

to the distributing mechanism. The apparatus was so arranged that it did not in any way encumber the fire door. The entire machine was driven by two small steam engines; one operating the crusher, the other the conveying apparatus. The conveying mechanism as well as the distributing device of this stoker were successful, but the coal crusher failed, due principally to its inadequacy. The engines together with a few minor details gave considerable trouble, although the complete combination gave a good showing when in proper repair. For it to be maintained in this condition, however, proved very expensive.

From the experience gained from the above stoker, a second one was designed and built, seeking to avoid all the weaknesses of the first while incorporating all its good points. The modified stoker, as finally placed into operation, used only one engine of a special slow speed design, special form of boot for the elevator carrying all the gearing to avoid encumbering the engine, an improved conveyor, a suitable coal crusher, and better coal distributing means. This stoker was finally placed into operation during the month of February last, applied to a consolidation freight engine. It soon developed that snow and moisture in the coal presented new difficulties by causing the fine coal to dry and cake in the elevator buckets, gradually filling them up, which so diminished the elevating capacity of the conveying mechanism that it clogged and stopped, finally resulting in a failure by breakage of the elevator chain. This trouble was probably due to wrongly-designed buckets, since the bucket elevating system as employed in the Street stoker works without trouble. During the operation of the stoker, steam was satisfactorily maintained and the apparatus worked smoothly. It is now proposed to do away entirely with the bucket elevator scheme and substitute in its stead helical screw conveying means.

The Hayden Stoker.—Nothing further in the line of development with the original type of Hayden stoker has been undertaken.

The Brewster Stoker.—The Brewster underfeed stoker was briefly described in proceedings of the Master Mechanics' Association for 1911. A stoker of this type was built and applied to a consolidation engine of the Erie Railroad. This stoker, being the first of its kind built and placed in operation, having incorporated in it several novel features, developed some weaknesses, as well as indicated the possibilities of certain of its new features.

The Strouse Overfeed Stoker.—No further attempt, as far as the committee was able to determine, has been made to perfect this stoker.

The Hervey Overfeed Stoker.—This stoker was placed in operation on a Mikado engine of the Baltimore and Ohio R. R. As far as developed, it is a distributor only, requiring coal to be shovelled into a hopper from which it is fed to a cylindrical hopper situated opposite the furnace door opening. From this latter hopper, the coal is distributed in the firebox by means of rapidly revolving vanes, fitted on a shaft driven through a chain and sprocket by a small engine. After several months of experimenting with this stoker, it was removed on account of the difficulty experienced with the distribution of the coal in the firebox.

Conclusion.—Generally speaking, in consideration of the foregoing review of the status of the mechanical stoker, the committee feels justified in concluding that decided progress has been made during the last year in the development of the mechanical stoker. While the perfection of the superheater and the brick arch have assisted in making possible a larger engine, it is considered, judging from these indications, that the advent of the perfected mechanical stoker will make possible a still larger engine.

Deterioration of Coal in Storage.—An investigation of the manner in which coal deteriorates under different conditions of storage, conducted by H. G. Porter and F. K. Ovitz, of the United States Bureau of Mines, showed that bituminous coals lost none of their heating value in one year when stored under water, and only 1 per cent. during open-air storage for the same period. Submerged storage is, therefore, considered to possess no especial advantages, except as a preventive of spontaneous combustion.

THE CORE ROOM: ITS EQUIPMENT AND MANAGEMENT.*

BY HENRY M. LANE.

(*Continued from page 19.*)

Fineness Tests on Sands.—It has already been stated that the size of the grains of sand should be as uniform as possible if the core is to have the maximum amount of venting space. The various sands examined were all tested for fineness, and some of the results are given in Table III. The amount recorded in each column is that which remained on the sieve of the size given at the top of the column. The percentage of material passing through the 100-mesh sieve is recorded in the column headed 100+.

The fineness number given in the right-hand column is arbitrary, and is intended for the comparison of different sands. It was reached in the following manner. The percentage which remained on each sieve is multiplied by the number of the sieve through which it passed, with the exception of that which remained on No. 20. This is also multiplied by 20 so as not to introduce a great error. These products are all added and divided by the amount of sand taken, which gives the fineness number.

TABLE III.—*Fineness Test.*

Sand.	Mesh.						Fineness Number.
	20	40	60	80	100	100+	
New England bank	3·7	11·6	17	11·6	13·7	40·6	68
Rockaway Beach	0·7	14·5	46	23·5	11	2·7	47
Michigan City core	0·5	9·8	41·5	35·75	9·55	1·8	50
Clay, Cleveland	2·8	30	11·0	4·9	10·3	41·7	64
Washed silica core	0·1	1·7	30·7	38·0	22·3	6·7	60
Lake Manistee, Mich.	0·2	4·3	9·8	12·3	12·4	60·7	83
Strawbridge, England	2·0	16·5	9·6	10·2	22·7	40·0	72
Mansfield, England	0·3	10·1	10·3	10·6	23·7	42·5	74
Burnt, Mansfield, England	0·1	6·3	7·2	10·7	27·9	43·6	77
Gangway, Moline, Ill.	1·8	7·9	10·9	9·6	12·5	55·7	78
Core, Pittsburg, Pa.	5·3	42·6	37·0	5·1	4·4	5·0	27
Falkirk, England	7·6	32·3	32·5	12·9	7·7	5·0	40
Silica, Ottawa, Ill.	0·1	72·8	21·6	3·1	0·8	0·7	26
Derby, England	2·5	8·3	46·5	27·3	10·5	3·1	49
Washed silica, Millington, Ill.	0·1	56·7	23·8	6·5	5·7	6·7	36
Magnesia, Millington, Ill.	4·3	48·6	20·7	5·8	6·8	13·4	41
Delray bank, Detroit, Mich.	1·5	0·55	5·1	5·75	21·15	55·05	76
Providence River	0·5	2·2	6·5	6·5	13·5	69·8	88
Yellow, sharp	0·1	30·5	48·5	13·9	2·1	3·6	39
Light moulding, Cleveland, O.	13·8	25·5	9·2	4·5	3·8	42·0	59
Silica, dust	0·7	1·2	14·1	10·3	9·9	62·3	82
Sugar, Cleveland, O.	17·1	36·2	23·2	11·5	5·3	5·5	37
Silica, Cleveland, O.	0·1	54·4	34·0	5·9	3·1	2·0	33

It is interesting to note that most of the sands adopted by foundrymen through experimental work have very nearly uniform-sized grains, or at least will leave more than half of the sand on two consecutive sieves. For instance, the Michigan City core sand has over 75 per cent. of its sand on the 60 and 80-mesh sieves; the washed Ottawa silica sand has 72·8 per cent. of its grains on the 40-mesh sieve, and 21·6 per cent. on the 60-mesh sieve, or over 94 per cent. of the sand on two consecutive sieves. The Del Ray bank sand so extensively used by brass foundries, is exceedingly fine, 55 per cent. of it having passed the 100-mesh sieve. As seen under the microscope the grains are clean and rounded, so that it has considerable vent. One of the fine sands used in the east is the Providence River sand, and of this 69·8 per cent. passed the 100-mesh sieve.

Specifications for Core Sand.—More investigation along this line and the co-operation of manufacturers will result in specifications for core sands for different classes of work. These specifications should include the relative fineness, the percentage of bonding material which will destroy oil, as determined by the dye test for colloids or some other test to be determined later, and the percentage of alkalies or lime.

Mineral Composition of Sand Grains and its Effect.—A good core sand should be free from shale or limestone pebbles if it is to be used with oil, since the shale is liable to form a fluxing ingredient. For some classes of grey iron work, sands carrying a considerable percentage of limestone pebbles are

* Abstract of paper read before the American Society of Mechanical Engineers.

used. These sands cannot be used with oil, but can be used with pitch compounds or glutrin. The first time they are exposed to molten metal, however, the lime which is next to the casting will be burned to quicklime. This will result in a considerable volume of carbon dioxide gas which must pass out through the vent, but the burning of the limestone to quick lime will partially disintegrate the core and make it easy to clean. If any of this old core sand is used in the new mix, the quicklime contained in it becomes a rather efficient binder, acting much as does flour or starch in that only the portion of the lime in contact with the sand grains is affected, the balance of it simply stopping up the vent.

At least two large foundries are making extensive use of a core-sand mixture containing heavily bonded loam sand and a quantity of limestone pebbles. For some classes of very heavy work no artificial binder is used, the clay in the new sand and the quicklime in the old sand being depended upon for that purpose. It is necessary in such cases, however, to give the cores a coat of blacking in order to peel the castings, and in making up the cores a large amount of coke has to be used to form vent passages.

Effect of Moisture on Volume of Sand.—In experimenting with a wide range of binders several sands representing different types were selected as standards and cores made with each series. The Ottawa silica sand, Michigan City sand, and the Rockaway Beach sand were three types of sharp sands, or sands carrying comparatively little bond, selected. One day the man making the cores reported that from a measured amount of sand he was obtaining more cores than formerly. Upon investigating it was found that he had taken

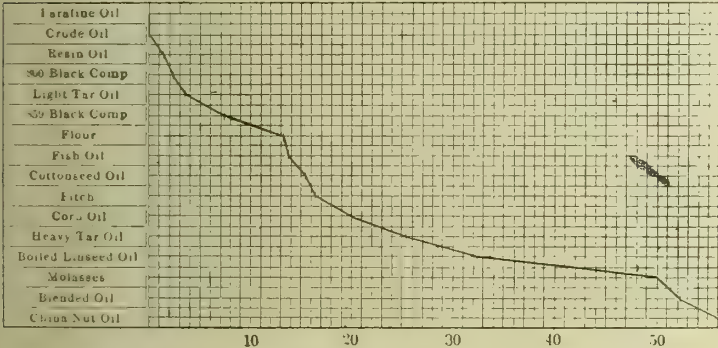


FIG. 2.—DIAGRAM SHOWING RELATIVE STRENGTH OF A NUMBER OF BINDERS.

one batch of sand from the bottom of a bin of Michigan City sand where it was wet and the next from the top of the adjoining bin where it was dry. To see if this would explain the matter a quantity of dry Michigan City sand was measured, 10 per cent. of water by volume added to it, the mass mixed over by hand, and an attempt made to put it back in the same measure from which it had been poured. It was found that 40 per cent. could not be returned to the measure. Experiments were then made by taking measured amounts of sand and adding first 1 per cent. and then 2 per cent. of water, and so on up to 20 per cent. or more. It was found that at first each addition of water increased the volume of sand until about 10 per cent. had been added, and that beyond this the volume began to decrease once more, until the volume of water was so great that the sand could settle out of it, when the volume of sand became very nearly the same as that for dry sand. The explanation is simple. In dry sand the grains slide past each other until the maximum number of bearing points are in contact. When there is just sufficient water present to form a film over each grain of sand, two grains coming in contact adhere and will not move further without the application of force. Fairly hard ramming will not even drive the sand back to its former volume.

The results of experiments with New England bank sand and Rockaway Beach sand are given in Tables IV. and V. The practical application of this is that if the men in the coreroom are allowed to take sand as it comes and measure it by volume they will be getting constantly varying ratios between the sand and the binder. If a given volume of dry sand is taken it will contain a certain number of grains and there will be a certain ratio to the binder. If the same volume of wet sand is taken there will be a very much smaller number of grains and hence a larger proportion of binder or smaller binding ratio, which will result in a stronger core, provided the mixing is properly done. All core sand should be dried before the binding material is mixed with it. If the core sand is measured by weight the introduction of moisture in it also introduces an error. Fortunately these errors tend to make stronger cores than would result from the use of dry sand, on account of the decrease in the bonding ratio, but this increase in the proportion of binder is an unnecessary and increasing expense which must be borne.

TABLE IV.—*Tests with New England Bank Sand from Waterbury, Conn.*

Sand, by volume.	Water, by volume.	Water, by weight, per cent.	Sand water added, volume.	Increased in volume, per cent.
500	5	0·77	590	18
500	10	1·54	680	36
500	15	2·31	750	50
500	30	4·62	790	58
500	45	6·93	830	66
500	60	9·24	810	62
500	75	11·55	810	62
500	90	13·86	800	60

TABLE V.—*Tests with Rockaway Beach Sand, Rockaway Beach.*

Sand, by volume.	Water, by volume.	Water by weight, per cent.	Sand water added, volume.	Increase in volume, per cent.
500	5	0·68	700	40
500	10	1·36	740	48
500	15	2·04	730	46
500	30	4·08	700	40
500	45	6·12	810	62
500	60	8·16	810	62
500	1,000	Flooded.	470	—

Effect of Damp Sand on Hand-mixed Oil-sand Cores.—In connection with the use of damp sands an interesting core was made from sharp lake sand and oil at the ratio of 50 to 1. The sand was fairly damp when taken from the bin, containing at least 3 per cent. of moisture by weight. The sand was spread on the coremakers' bench, the oil measured and poured over it, and the batch thoroughly mixed by hand, until the oil appeared to be evenly distributed. A little water was then added to temper it thoroughly and again rubbed over two or three times by hand. It was not passed through a riddle, however. A batch of cores were made from it and baked. When they came from the oven small white spots of unbonded sand appeared on the surface and the sand could be poured from these. A number of holes less than $\frac{1}{16}$ in. wide and a little over $\frac{1}{8}$in. high, extending into the core for $\frac{3}{8}$in. were seen all over the surface of the core.

Another batch of sand was mixed in the same way, and passed through a No. 4 riddle once. Cores were made from this and baked. They were found to contain little spots where a dozen or more grains of sand had adhered and the water on them had prevented the oil from covering them. These spots of dry sand fell out leaving small spots on the face of the core and upon breaking the same condition was found to exist through its entire body. A portion of the same batch was put in a mixing mill and ground for two minutes. Cores made from this showed perfectly uniform results.

These experiments clearly showed two facts: first, damp sand should never be used in making up core mixtures, and second, core sand should be ground or thoroughly mixed to ensure the incorporation of the oil with the sand and the covering of every grain of sand with the oil.

Binders Tested.—The results of one series of tests on binders are shown in Fig. 2. The paraffin oil and crude oil which are frequently used in core oils for blending show no binding power whatever, or at least they broke at less than 1lb. per square inch. The black compounds tested in this series were

not suited for use with the Rockaway Beach sand, but should have been used with those containing some loam. The pitch referred to is what is known as parolite, a product furnished by the Standard Oil Company. A sample of raw linseed oil was also tested in this series, but could not be broken on the testing machine then in use. Since this time experiments have been tried and oil sand cores made at the ratio of 1 to 50, breaking as high as 160lbs. per square inch in tension.

Cores for Steel Foundry Work.—The selection of the proper materials for use in any given core room depends upon local conditions as to supply of core-forming materials and the product being manufactured. A wider variety of materials can be used in connection with grey iron work than in most other classes of work. Heavy open-hearth steel work requires the best materials. Both the mould and the cores must be made of silica sand and nothing that has a tendency to fuse at low temperatures can be employed. At the same time the cores must be of such a nature that they will crush readily before the metal as it shrinks. This has brought into use many different mixtures all having the same object in view. Flour or flour and molasses are sometimes used as binders and the cores baked until the bond is practically destroyed so that the core is rotten. Core arbors and core rods are relied on to hold the material together and the surface is thickly coated with a silica wash which gives a strong skin to the core. Such a core will usually resist the action of the molten metal and crush readily when the casting shrinks. Others use both clay and sawdust in their core mixtures, the sawdust burning out and allowing for shrinkage and the clay acting as a binder. The burning of the sawdust frees the clay and permits the cleaning of the core. In one light-work steel foundry shop a core made of silica sand, Welsh Mountain clay, and sawdust is used, the core being baked until the sawdust is partially charred.

For work with core mixtures in which a binder like glutrin will sweat to the surface such a mixture could be developed to good advantage for steel foundry work, as a core of this kind has a hard skin and a rotten or soft interior. All such cores, however, have to be baked carefully at a certain temperature, for if the skin is burned there is nothing left of the core. Glutrin is used in steel facing sand and in many clay and silica sand core mixtures.

Cores for Brass, Bronze, and Aluminium.—The other extreme in the core field is found in the brass and bronze foundry. Here the temperatures encountered by the cores are much lower, and greater diversity of sands and binders can be employed. In a case of this kind what is needed is a core with a close surface which is still free venting enough to permit the mould to be filled quickly and the gases to escape readily. Clay is out of place as a binder in brass and bronze work and the material used should be of such a nature as to burn out at a rather low temperature.

In dealing with aluminium a metal with maximum shrinkage and minimum hot strength is encountered. This requires a core that yields readily and softens as quickly as the metal strikes it. Two courses are open: to use a mixture giving a core with a soft interior and practically all the binder on the surface so that as quickly as the surface is disintegrated the core can be readily crushed; or to use a binding material which softens as soon as heat strikes it whether it burns or not. Resin is the only binder which fully meets this latter requirement, and it is frequently used to good advantage in aluminium work. These cores clean out readily if the castings are taken from the mould hot and cleaned out at once, but if they are allowed to get cool the resin cores harden once more and it is almost impossible to get them out.

Cores for Grey Iron and Malleable Iron.—For grey iron or malleable work the core problems to be met are almost infinite. In the radiator shops and in stove foundries producing gas range burners it is necessary to have cores which are exceedingly strong and free-venting and which will stand being entirely surrounded by metal with the exception of a small print. This means a core made from sharp sand and at present all such are of oil or mixtures of oil and glutrin as binders.

Oil-sand cores have one advantage possessed by few other binders, that a core made from clean sand and oil has no tendency to absorb moisture and can be kept without losing strength for an indefinite length of time. The writer has cores in his possession, now nearly five years old, made of linseed oil and clean sand, some of which were used after they were four years old and seemed to give as good results as the new ones.

A core for the most exacting requirements met by oil-sand mixtures must have a tensile strength of at least 75lbs. per square inch. In such mixtures it is usually the most economical to employ only high-grade materials and particular care must be taken to see that the sand contains no loam which will destroy the bonding value of the oil. The high price of linseed oil makes the cost of the old standard binder almost prohibitive and has led foundrymen to look for cheaper materials. All of the paint and varnish oils, including China wood, Soya bean, corn and cottonseed oils have found a place in the core-oil trade. The regular blended oils on the market also carry resin and neutral oil. As a rule the neutral oil does not add appreciably to the binding power of the compound, but it does serve to carry the resin into the mixture and to give a waterproof oil of sufficient strength for ordinary work at a much lower cost per gallon than the old stand-by linseed. As linseed oil, however, is the ultimate standard of excellence for all core oils, some firms prefer to use it and either to dilute it themselves or to use glutrin in the mixture with it. In many grey iron and malleable foundries flour or dextrine is used as a binder and for some classes of work they give entire satisfaction.

Cost of Strength in a Core.—In solving any core-binder problem the ultimate cost is the guiding factor. To determine the cost of a cubic foot of core several points must be considered: (1) the strength of the core mixture both green and dry; (2) the character of the surface which the core presents to the metal; (3) the question of the percentage of vent area in the core; (4) the ability of the core to resist moisture; (5) the ease with which the core can be cleaned from the casting; (6) the character of the fumes or gases given off during the baking of the core and when the mould is poured; (7) the number of cores which a man can make in a day from a given mixture; (8) the cost of drying; (9) the expense of the rigging involved with the use of a given binder.

The strength of the green mixture is important in cases where cores must stand at a considerable height above the plate during drying, and if the core has any overhanging bodies it must possess sufficient green strength to carry these. Green strength may be afforded by using a bonded sand, that is, a sand containing clay, or by using flour, dextrine, or some other glutinous or starchy material in the mixture. The strength of the dry core is governed by the amount of pressure it must resist as the metal enters the mould. All cores tend to float as the metal enters, and if not sufficiently rigid to resist this tendency are likely to be broken or displaced.

Cores must also have sufficient strength to enable them to resist handling. The strength of core mixtures in use in the foundries in which we have carried on experiments varies from less than 5lbs. to over 100lbs. per square inch. The proper strength for a given condition can be determined only by experience, but after this has been decided, any other sand or binder mixtures can easily be compared with the standard by suitably testing the new one. Foundrymen have generally adopted a bar 1in. square and broken it on supports 12in. apart. This is suitable for oil-sand and fairly strong mixtures, but does not give good results for mixtures having low strength. For these the tensile method using a delicate machine is to be preferred or bars 4in. or 6in. long and 1in. square may be made and broken in the middle.

Under the second heading must be considered the character of the surface presented to the metal, its ability to carry off the air or gases displaced by the metal as it enters the mould, its ability to resist the cutting action of the metal as it flows into the mould, and the freedom with which the burned core separates from the surface of the interior of the casting. As has already been stated, in the case of metals which have extreme fluidity and a tendency to search out all small openings in the core, it is necessary to use a mixture which will present a close uniform texture, the voids or spaces of which are so fine that the metal cannot flow into them. In the case of such metals it may be necessary to use some facing or blacking on the core to close partially the spaces or voids and also to make the core clean out more readily. Cores for cast-iron water pipe and a large variety of similar grey iron work are given a coating of blacking and the interior faces of the mould made to peel just as well as the exterior. If the core itself does not present a proper surface to the metal it must be

considered whether it would be cheaper to select a material which does, or to treat the surface of the core in such a way as to improve it.

Under the third heading, the percentage of venting area, must be considered the size of the sand grains and their character: also the character of the bond and the extent to which it blocks the vent. In the case of castings which are entirely surrounded by metal with the exception of a small print, as for instance, gas stove burners, the sand mixtures must have a maximum amount of vent and a minimum amount of gases to be driven out, while in the case of aluminium the metal solidifies so quickly that a very small amount of gases has to be taken care of. The thickness of the casting that is to surround the core also has an influence on this as it determines the duration of the high degree of heat.

Under the fourth heading, the resistance to moisture, must be considered the length of time the cores remain in the moulds and the manner of handling and storing them. If high-grade oil-sand cores are used, their moisture-resisting properties are such that no ill effects need be feared from leaving them in the mould several hours before it is poured or in connection with their storage, but many other binders show a tendency to absorb moisture. Where this is the case, if there is a considerable saving in the use of one which absorbs moisture, it may be necessary to see if some means cannot be found for so handling the cores as to minimise their exposure to moisture. If they are kept in a dry place and are introduced into the mould only a short time before pouring, there will be no trouble on account of dampness and the saving in the cost of binder may more than compensate for the additional handling.

The fifth heading, ease of cleaning, is one of the important problems in the expense of making castings. A proper core mixture should rattle out without any difficulty, leaving a good smooth interior surface. If this is not so, some means must be secured of freeing the surface from the metal or of making the entire core of such a nature that it will soften under the action of the heat. In the case of brass and bronze cores, they are very largely blown out by dipping the hot castings into water, the steam formed blowing out the core. Iron castings cannot be so treated, hence the core must be compounded and baked so as to clean freely. One of the most common causes of difficulty in the cleaning room is the use of an excess of binder in the core room, or the use of sands which are too heavily bonded, that is, contain too much clay.

Under the sixth heading, the character of fumes, must be considered both the effect of fumes in the core-room and foundry. With regard to the character of fumes, certain oil mixtures give off very disagreeable odours after the cores are withdrawn from the oven and placed in the racks to cool. If less offensive mixtures which are equally efficient can be found it will greatly improve the working conditions of the core-room men; if not, ventilating devices should be provided to draw these fumes away from the coremakers. In the foundry the importance of this question depends to a large degree upon the volume of the cores used for each individual casting. If there are only a few small cores in each mould the volume will not be sufficient to trouble the workman, no matter what binder is used, but if the mould is largely composed of cores it becomes an important item in the comfort of the moulders at pouring-off time, a great many castings having been lost on account of careless pouring of a moulder in hurrying from the stifling fumes of the surrounding moulds. Whale oil and fish oil give particularly bad fumes in these cases, though they form excellent binders. By lighting the gases as they come from the vents in the mould the disagreeable odours can frequently be reduced, but even then they may be sufficient to make a change of binding materials desirable. More and better work will result.

The number of cores per man per day is influenced by the character of the binder, since if the material tends to stick to the core box, the workman cannot produce as many cores as in a free working material. In many binders the trouble with the sticking was found to be due to too strong a core mixture, and as soon as the proportion of binder was reduced the trouble disappeared. In the cost of drying, the length of time it takes to dry each different class of cores when using different binders determines the capacity of the core ovens, their fuel consumption, and the floor space which must be devoted to equipment of this kind. Quick-drying core mixtures increase this capacity, and so decrease the plant expense.

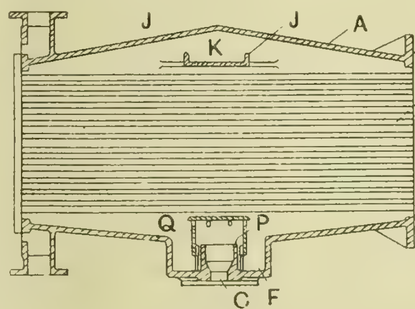
High-grade oil-sand cores made from clear sand and oil have no green binding power, and hence they must all be provided with driers which support the core throughout its entire length, or the cores must be bedded in open, clear, sharp sand containing no binder. One of these procedures requires a considerable outlay for driers, and the other an expenditure of time for bedding in. If the output from a given core box or pattern is to be limited, it may pay better to use a mixture having some green bond, so that the cores may be allowed to stand on one end on the plate or be supported in some other convenient manner which will avoid the making of driers. If very large outputs are required the driers will be found the most economical course.

(To be continued.)

HALL-BROWN'S CONDENSER.

THE condensers shown in the accompanying illustrations have been designed and patented by Mr. E. Hall-Brown, 150, Hyndland Road, Glasgow, with the object of preventing the flooding of the cooling surface by water carried into or towards the condenser along with the exhaust steam, and at the same time of enabling the water of condensation to be withdrawn from the condenser at a temperature which is high relatively to the pressure within the condenser and comparatively free from oil in a state of suspension. The arrangements are specially applicable to condensers intended to work at or about atmospheric pressure and to receive the exhaust steam from auxiliary steam engines such as the engines of winches, pumps, &c., on board ship. Figs. 1 and 2 show longitudinal and transverse vertical sections of the condenser, and Fig. 3 shows a modification. In Figs. 2 and 3 the condenser tubes are omitted.

Referring first to Figs. 1 and 2, the exhaust steam, carrying with it a certain amount of water, as is usual, is admitted by way of the port B to a duct E which extends from the top to the bottom of the condenser. When the water, which has run along the bottom of the exhaust pipe leading to the condenser, enters this duct, it runs through the lower branch of it and through the port G into the well F at the bottom of the



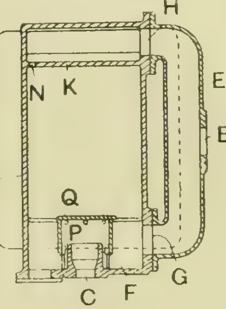


FIG. 1. HALL-BROWN'S CONDENSER. FIG. 2.

condenser. Moreover, the impact of the steam on the side of the duct opposite the port B causes the deposit of a large proportion of the suspended water on the wall of the duct, which water runs down to the well F. The greater and drier portion of the steam ascends in the upper branch of the duct and enters the condenser proper at the top by way of the port H. This steam passes into the condenser between the top wall of the latter and a baffle plate or tray K which is arranged parallel to the top wall of the condenser, and then passes over the sides J of this tray in order to obtain access to the condenser cooling surface which consists of tubes M through which relatively cold water is circulated. The plate or tray collects most of the suspended water which has not been separated out in the duct and also water formed by condensation of the steam after it has entered the duct. The water thus collected on the tray is allowed to flow through holes N in the latter and, without being cooled by contact with the tubes M, to run down the side of the condenser to the well F at the bottom thereof, where it mingles with the water which has passed directly thereto by way of the lower branch of the duct E. The water produced by the condensation of the steam on the tubular cooling surface falls as rain to the bottom of the condenser. This rain is relatively cold. While the greater

portion of the steam enters the condenser proper at the top, a certain amount passes down through the lower branch of the duct E and is condensed at the bottom of the condenser by the rain of condensed steam water from the tubes. The steam acts to heat this water before the latter falls into the well F.

In order to separate the oil from the water at the bottom of the condenser, the water is withdrawn from the condenser over a weir P, which is of annular form and which is guarded by a baffle plate Q in such a way that the water which flows over the weir is drawn from below the surface of the water in the well F. The oil which collects on the surface of the water is thus not drawn over the weir. The water is discharged through the port C. Separate means may be provided for withdrawing the oil either continuously or intermittently. As a large proportion of the water withdrawn from the condenser has not been in contact with the tubular cooling surface, and as that portion which has is thereafter heated by a portion of the entering steam, the mean temperature of the water at exit from the apparatus will, it is claimed, be considerably higher than in condensers in which the whole of the fluid delivered by the exhaust pipe is precipitated on the cooling surface.

In the construction just described the amount of heat given up by the entering steam to the water of condensation dripping from the tubes, while sufficient to be of advantage, is necessarily comparatively small. In order that the water of condensation may be raised to a higher temperature by the entering steam, practically the whole, instead of only a small portion, of the entering steam may be brought into direct contact with the water of condensation. This is accomplished by employing the construction of condenser shown in Fig. 3. In this arrangement the steam entering by the port B passes upwards through the port R and down through the duct S, while the water carried into the apparatus with the steam runs down the duct T into the well F, where it mingles with the water of condensation from the condenser proper, which flows into the well by way of the port U. The combined waters then flow over the guarded weir P into a spraying nozzle V, which delivers the water in a finely divided or atomised state into the chamber W. The sides of this chamber are perforated; and the chamber is provided with a jacket X into which the steam passes from the duct S. The steam passes through the perforations in the sides of the chamber W and mingles with the finely divided water, part of the steam being condensed thereby. The uncondensed steam passes upwards by the duct Y, enters the condenser proper by the port H, and is condensed on the tubular cooling surface. When the steam enters the condenser proper at the top, a tray K may, if desired, be provided as in the construction of apparatus illustrated in Figs. 1 and 2. As the portion of the water of condensation which has come from the cooling surface of the condenser is considerably colder than the steam, the mean temperature of the water which enters the chamber W is colder to a greater or less extent than the steam and therefore acts to condense a portion of the steam and in doing so to be itself raised in temperature. The water is withdrawn from the apparatus through the outlet C at the bottom of the chamber W, at a temperature closely approximating to that of the steam. The spraying device V may consist of a convergent nozzle with longitudinal slits extending backwards from the orifice, and acts in conjunction with a baffle or splash plate D which is placed opposite it and on to which the water, or the greater part of the water, which is delivered through the nozzle, is caused to impinge. A very small, and usually negligible, amount of steam will pass down the duct T from the admission port B and be condensed on the surface of the water in the well F. The remarks made in describing the construction shown in Figs. 1 and 2 as to the withdrawal of oil, apply equally to the construction shown in Fig. 3.

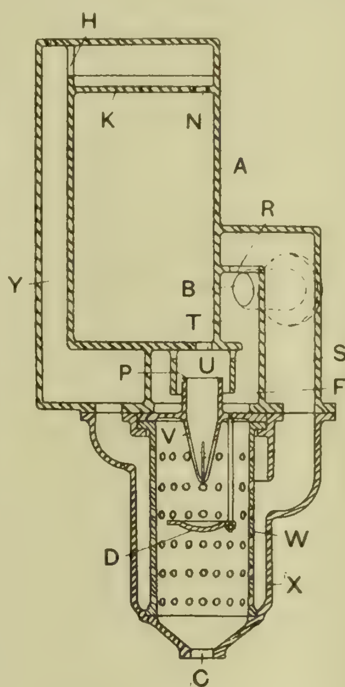


FIG. 3.
HALL-BROWN'S CONDENSER.

MODERN WELDING PROCESSES.*

WITH SPECIAL REFERENCE TO FLAME WELDING.

BY H. R. COBLEIGH.

(Concluded from page 821, Vol. XXIX.)

Acetylene Generation.—All methods of acetylene generation are alike in the materials used, calcium carbide and water. While any carbide could be used, the calcium form is the only one obtainable on the market in large quantities and at a reasonable figure. It is a product of the electric furnace, being formed only at a very high temperature from a mixture of ground coke and lime in the proportions of 9 to 14 by weight. The reaction is $CaO + 3C = CaC_2 + CO$. When calcium carbide and water are brought together acetylene is evolved with slaked lime as a residue expressed by the following equation: $CaC_2 + 2H_2O = Ca(OH)_2 + C_2H_2$.

Commercial carbide yields from 4½ to 5 cub. ft. of acetylene per pound. Lump carbide in sizes of 1¾in. by ⅜in., known as "nut," is claimed to yield from 5 to 15 per cent. more acetylene than finely divided carbide, probably due to more or less slaking of the latter by moisture in the air. For that reason generators capable of using the lump carbide claim a certain advantage over those limited to the use of the crushed form.

Two kinds of generators are used, known from their manner of feeding as water-feed or "water-to-carbide" generators and carbide-feed or "carbide-to-water" generators. The first is very little used because of the disadvantage that the apparatus gets very hot and the gas is not likely to be so good. This is due to the tendency of the gas to become overheated and to some extent to be converted into oily matters, an effect known as polymerisation. Where this has occurred it is indicated by a yellowish or brownish staining of the residue. It can be avoided where care is taken properly to water-cool the apparatus.

An example of the most approved apparatus of this type is that recently installed in the Santa Fé shops at Topeka. It consists of cylindrical iron cells placed horizontally, each fitted with galvanised iron drawers of six sections for holding carbide. The water is admitted to each of the end sections and the gas generated is carried away in pipes. When the carbide becomes exhausted in the end cell, sufficient water has accumulated to run through a V-shaped opening in the partition to the next section, after which the drawer is withdrawn and recharged. As a cell is opened the water supply to it is automatically cut off. These generating cells are kept submerged in running water to keep the temperature of the gas as low as possible. Any cell can be inspected or re-charged without interfering with the operation of the others. The gas is further cooled and washed by being passed through water before it reaches the holder.

Where the reverse manner of feeding is used and the carbide is dropped into the water, the gas is washed as it is evolved, and it and the apparatus kept cool. In these generators it is well also to have an abundant supply of water in the bottom. The generally accepted rule now is a gallon of water to each pound of carbide.

The carbide-feed machines may again be divided into two classes, gravity feed, where some sort of a valve is used to release the carbide, and forced feed, where usually by means of clock work the carbide is forced off a plate or some similar device. In both types the action of the feed is dependent upon the pressure of gas within the machine. As it falls more carbide is dropped into the water and as the pressure rises the feeding is arrested. Both generate acetylene at sufficient pressure to be used directly in the pressure or positive-mixture types of torches. A necessary feature of all types of generator is a water-sealed flash-back chamber or its

* Abstract of paper read before the American Society of Mechanical Engineers.

equivalent to make communication of the flame to the generator impossible. Safety devices interlock the various movements of valves operated when re-charging the machines.

Low-pressure generators such as are used for lighting are suitable for supplying torches of the injector type. Their principal difference from the types just referred to lies in the feed control, which is usually by a bell instead of a pressure diaphragm.

Where a generator is carried on a portable outfit the water-to-carbide type is probably the safest, since a carbide-feed type would be more likely to generate gas when jarred. Some argue that a generator should never be carried on a portable outfit, but that compressed gas tanks should be used. This calls for the explanation that whenever compressed acetylene is spoken of what is meant is dissolved acetylene, for the gas becomes very explosive when compressed to above two atmospheres. In 1896, Claude and Hesse, two French engineers, discovered that acetone is a remarkable solvent for acetylene. For each atmosphere or pressure it will dissolve 25 times its own volume of acetylene, and in this condition the latter is not explosive under heavy pressure. The acetone is placed in tanks containing porous material, so that there are no spaces for the gas to separate and collect in, and the acetylene is compressed into them. Acetylene in this form, although costing twice as much as when generated, is very convenient in outside repair work where portability is a feature.

Of all hydrocarbons, with the possible exception of liquid and Blau gas, acetylene possesses the greatest proportion of carbon, 92·3 per cent., the remaining 7·7 per cent. being hydrogen. It is therefore most nearly gaseous carbon, for there is no known means of obtaining a high enough temperature to gasify pure carbon. It gives about five times as much heat per cubic foot as hydrogen and a flame of greater intensity, the temperature being, as has been mentioned before, 6,300° Fah.

Oxygen Generation.—Oxygen generation is of three classes, chemical, electrolytic, and atmospheric, to each of which except the second there are sub-divisions. Chemical oxygen production is of two kinds, wet and dry, and of each there are several variations. The wet process at the Santa Fé shops consists of boiling in a water-tight tank a saturated solution of bleaching powder, or calcium oxychloride, to which is added at regular intervals a saturated solution of five parts iron sulphate and one part copper sulphate. A mechanically-operated paddle, agitating the mixture, facilitates the release of the gas. The oxygen passes off at the top and the residuum remains in solution to be drawn off before the tank is discharged. The water in the tank is heated by the exhaust steam from the oxygen compressor. From the generator the oxygen is passed to a water scrubber to remove the chlorine and foreign matter, and for a final cleaning the gas is passed through a second scrubber containing a solution of caustic soda, which also serves as a water seal to the gasometer to which the clean gas is delivered, and from which it is drawn by the compressor and stored in tanks at a pressure of 85lbs.

The Lavoisite process is another of the same class, which, however, evolves oxygen directly under pressure by the simple addition of hot water to a powder of secret composition. The Lavoisite powder is received in a drum which is inverted over the top of the generator and connected with it by means of a special valve arrangement in connection with the cover of the drum. The contents of the drum are discharged into the generator, the drum removed, and the generator manhole cover replaced and screwed down. Hot water is then pumped into the generator until the charge is exhausted, the oxygen in the meantime passing through a scrubber to the distributing main or storage tanks. When the generation is complete the hot water is shut off and cold water pumped in until all of the gas remaining in the generator is displaced. When the generator is clear it is ready for a new charge.

Still another wet process used, a powder sold under the trade name of Epurite, a mixture consisting of 20 parts chlorate of lime, one part sulphate of copper, and three parts sulphate of iron, which when brought into contact with water evolved oxygen. One pound of the material produced about 8 cub. ft. of oxygen. The generating apparatus deteriorated so rapidly and the cleaning of it was so mussy that it was soon abandoned.

The most common chemical process is the dry evolution of oxygen under the influence of heat from a mixture of 100 parts by weight of crystallised chlorate of potash and 13 parts of manganese dioxide, contained in a sealed retort. The gas requires thorough washing in a solution of caustic soda to eliminate its chlorine. It can be compressed after washing in a two-stage compressor, or generated under pressure by using heavier retorts and heating longer or more intensely.

A somewhat similar process is that using oxygenite, the trade name for a mixture of perchlorate of potash with infusorial earth and charcoal. When ignited in a closed retort it burns, evolving an excess of oxygen over that required for its own combustion. The reaction under the influence of heat is $KClO_4 = KCl + 2O$. The necessary pressure is obtained without subsequent compression.

The fault with most chemical processes is the difficulty of eliminating the poisonous chlorine, which also has a tendency to impair the weld. With all processes using manganese dioxide precautions are necessary for obtaining pure oxide, as carbon or hydro-carbons in any form, even traces of oil from a compressor which should therefore not have cylinder lubrication, must be eliminated before compressing the oxygen on account of their combustibility. The purer the oxygen the better, as even small percentages of impurities decrease the economy and the strength of the welds. Oxygen produced by the electrolytic process is 99 per cent. pure, the only impurity being a trace of hydrogen.

The International Oxygen Company's system makes use of a group of oxy-hydrogen generators, each an electrolytic cell, through which, by the passing of an electric current, water containing some alkali is decomposed. The oxygen collects at the positive electrode and the hydrogen at the negative electrode, which is the iron tank containing the solution. The positive electrode is a perforated tank surrounded with an asbestos sack. The two gases as they collect on their respective electrodes are effectively separated, and the bubbles rising as they collect are entrapped in compartments at the top, separated from one another by a water seal.

Atmospheric oxygen is next in purity to electrolytic, its only impurity being nitrogen. The process used by the Linde Air Products Company at its various works, from which it distributes for sale the gas compressed in tanks, consists first in the complete liquefaction of the air to be resolved by a process of accumulative cooling. The liquid thus formed is then submitted to a process of rectification at the same time that an almost complete transference of heat is obtained from the compressed air entering the apparatus to the liquid air thus formed. In this way 95 or 96 per cent. pure oxygen can be obtained. Air is compressed by a four-stage compressor with practically adiabatic compression, and after each stage the heat of compression is removed by passing the air through a cooler, through which water is circulated. The carbon dioxide and moisture in the air are readily eliminated by freezing, and the oxygen becomes liquid while the nitrogen is still gaseous. This explains in brief the principle of the separation without going further into the details of the apparatus. The equipment is in duplicate to permit continuous working, so that when ice, due to entrapped moisture, has accumulated in one the other can be put in operation while the first is allowed to thaw.

Another atmospheric process, partly chemical, employs barium oxide first to absorb and then liberate oxygen. With a constant pressure barium oxide will absorb oxygen from the air to form the peroxide at a temperature of 600° C. and at 850° C. will again give off the excess oxygen. With a constant temperature of 700° C. the same effects can be accomplished by varying the pressure, the peroxide being formed at $1\frac{3}{4}$ atmospheres and the excess oxygen liberated by diminishing the pressure.

Pressure Regulation.—An important device between the torch and the source of the gas, whether oxygen, acetylene, or hydrogen, and whether from pipe line, generator, or tank, is the pressure regulator, for with all torches it is necessary to maintain constant pressures to secure uniform work. Regulators vary somewhat according to the gas, and in minor details in different makes. The function of the regulator is that of a reducing valve to maintain any set constant pressure not exceeding that of the source, and there is always combined with it a pressure gauge on the discharge side to show the pressure admitted to the torch. Where the gas is taken from portable cylinders an additional gauge is provided on the other side of the regulator to show the state of depletion of the compressed gas in the cylinder.

Use of the Torch.—The rest of this paper applies practically to all kinds of gas torches, and especially to the oxy-acetylene and oxy-hydrogen torches, unless an exception is noted. The utility of all torches lies in their ability, on account of the high temperatures of their flames, to bring the part of the metal acted upon to molten condition before the heat supplied can be dissipated by conduction and radiation, therefore making possible local recasting. Some heat is, of course, lost, but probably not without an advantage in reducing trouble from expansion and contraction.

The envelope of the flame starts the heating of the metal in advance of the actual work, and the local heat at the point of the inner cone follows. Metal, thicker than ⅛in., to be joined should be scarfed or chamfered to give a V-groove in which to work, permitting penetration of the flame to the bottom of the joint. It is usually necessary, except on thin sheets not scarfed, to add metal to the joint. This is melted in from a wire or strip generally of the same material as those being joined, which is called a soldering or welding stick. In making the weld, after the metal adjoining the joint is itself in running condition, molten metal is added drop by drop from the stick until the groove is filled, and where it is allowable a little excess is built on to make the joint fully as strong as the rest of the work. If the metals joined are dissimilar, a stick of approximately the same material as that of the two being joined which melts at the lower temperature should be used. Otherwise the added metal will chill when falling upon the other molten metal. Sealing powders are sometimes used for welding cast iron and aluminium, but less so than formerly, since experience has shown them to be seldom necessary. The function of a scaling powder is not primarily that of a flux to prevent oxidation, but to remove any scale in the weld and make the metal more fluid. With proper manipulation of the torch, which is now better understood, scale is not so apt to be formed in the first place.

A torch or nozzle is selected which will give a size of flame suitable for the work in hand, which must be large enough to do the work thoroughly in the shortest time without consuming unnecessarily large quantities of the gases. With the proper blowpipe flame the heat is kept local, so that expansion and contraction influences are minimised. It is not good practice to hold or grip anything to be welded so that it cannot adjust itself for expansion and contraction. Therefore, long seams, longitudinal or circumferential, should be first spot-welded or tacked at intervals of 6in. to 12in., and after tacking all bands should be removed. Castings to be welded should be preheated all over if there is any chance of having contraction strains produced when the weld cools. The preheating should not go above 500° Fah. if there is any serious consequence from permanently distorting the casting. The preheating, usually done in a forge, or a coke fire, or by a gas-air blowpipe, saves the corresponding application of heat with the torch using more expensive gases, and also saves the latter when the welding is being done, by reducing the loss of heat by conduction and radiation.

The welding of aluminium is something of an art in itself. This metal does not behave like any other. It first becomes pasty when heat is applied, and does nct become fluid until very near the burning point. It is quite common to facilitate the uniting of the metal by working it with an iron spatula until the joining parts amalgamate. Fluxes are often used for aluminium welding, the functions of which are to reduce the invisible oxide film always present on the surface of metallic aluminium, so that the parts flow together, and to protect the hot metal from the air and further oxidation.

Very thin metals are most easily welded when the weld is performed on the edges turned up as flanges back to back, but this is not necessary, and those expert at the work can now butt-weld thin sections without even adding metal from a stick. Most depends on moving the torch steadily at the proper speed, for it is very easy to let the torch dwell too long at one spot and burn a hole through, so that metal has to be added, and a less neat joint results.

In all welding judgment plays a large part, and a knowledge of metals and their characteristics is a great help. It is a nice determination, for example, as to just how far on each side of the joint to carry the heating, since an error either way is likely to produce a poor weld. Expansion and contraction must always be taken into consideration, otherwise internal strains will occur, which are likely to produce a new crack when the metal cools. Preheating, as before explained, removes most of the difficulty. As to the strength of welds, much depends upon the operator. Welded steel work can easily compare with double riveting and caulking and in some cases can attain the strength of the butt strap joint.

With flame welding nearly all kinds of metals can be welded, cast or wrought iron, steel, brass, aluminium, copper, &c. Skill and experience count for much, and many things originally thought impossible are now being quite readily accomplished. A consistent study of materials and their composition and structure has led to the overcoming of many difficulties. The behaviour of metals under the influence of heat, particularly their expansion and contraction, requires study and allowances in making welds. Not a little progress has already been made in the heat treatment of welds after they are made to restore largely the original properties as to structure and strength.

The flame processes are especially valuable in the welding of metal from No. 20 gauge up to ⅝in. thick. Work that has to withstand high heat, such as boilers, annealing boxes, &c., can be satisfactorily welded, and it is probable that this method will more and more take the place of riveting, particularly since in many cases it is cheaper. All kinds of tanks, especially those designed to contain anything that would tend to eat its way around rivets, are better for being welded.

It is apart from the purpose of this paper to go into an extensive enumeration of the specific kinds of construction and repair work possible by arc and flame welding. No list would be long complete, for new applications are continually being found, and the more usual ones are already familiar to all. Among the things that are still difficult or impossible are the welding of very heavy sections, this being better left to thermit welding, flame welding being generally too expensive, and the greater pressures of the gases necessary to secure deep penetration being likely to produce crystallisation of the work structure; brazed and galvanised articles, on account of the volatilisation of the zinc, producing porous spots; and the welding of aluminium to other metals.

Arc and Flame Cutting.—Although the welding, and not the cutting of metals, is our subject, it would hardly be proper in a discussion of arc and flame welding to make no reference to the scarcely less important function of the same implements used in the cutting of steel and wrought iron. These are the only metals that can be so cut, some alloy steels being excepted. The torches using hydrogen have the advantage in the cutting of heavy sections, being able to cut to a greater depth on account of the greater penetration. With such torches cuts have been made in metal 24in. thick, while 12in. to 15in. is the limit that has been accomplished with the oxy-acetylene torch.

For cutting, the torch has an additional jet of oxygen under high pressure, up to 125lbs. to 225lbs. The acetylene or hydrogen and low-pressure oxygen preheat the work, and the high-pressure jet following in the wake of the heating flame does the actual cutting by producing a very high rate

of oxidation. Part of the metal is removed as iron oxide, and the heat of the combustion melts the rest, so that it runs out of the cut.

Reference to the time and cost of doing work by any of the various processes is purposely omitted here since so many variables enter into such considerations that any figures that might be given would probably be more misleading than instructive. Both are matters that can be determined only by experimentation under the conditions that will apply, and a result in one field can never be taken as a criterion for another.

Machine Welding.—A very large field for ingenuity has been opened in connection with all of the welding processes, in the devising of means for the mechanical guiding of the welding or cutting implements, or otherwise facilitating the operations. Most of this work has been done naturally by the users of the apparatus, particularly where the work they have to do is largely in duplicate. Unfortunately these are seldom made public, either because the user has no inclination to enter into the manufacture and marketing of them, or because he does not wish his competitors to have the advantage of their use that he enjoys.

Attention is just beginning to be given to mechanical means for guiding the torches when doing welding and cutting. For neat, uniform work of both kinds they are practically imperative, and save greatly in time that would otherwise be necessary to do careful work. With a cutting torch mechanically guided and and moved at a uniform rate, circular or straight cuts can be made giving as smooth an edge as though cut by a saw or any other tool. Especially for thin sheet welding machines are desirable because of the precision with which the torch can be moved.

INTERNATIONAL CONFERENCE ON WIRELESS TELEGRAPHY.

AT the International Conference on Wireless Telegraphy, which was concluded on Friday last, several important decisions were arrived at. The conference, at the request of the British Government, gave special consideration to the question of the use of wireless telegraphy for the prevention of disasters at sea, and after full discussion passed unanimously a resolution, proposed by the British delegation, in favour of the principle of compulsory equipment of ships with wireless telegraphy. The text of this resolution was as follows: "The International Radio-Telegraphic Conference having examined the measures to be taken with the view of preventing disaster at sea and of rendering assistance in such cases, expresses the opinion that in the general interests of navigation there should be imposed on certain classes of ships the obligation to carry a radio-telegraphic installation. As the conference has no power to impose this obligation, it expresses the wish that the measures necessary to this end should be instituted by the Governments. The conference finds it important, moreover, to ensure as far as possible uniformity in the arrangements to be adopted in the various countries to impose this obligation, and suggests to the Governments the desirability of an agreement between themselves with a view to the adoption of a uniform base for legislation. Lastly, the conference recommends to the Governments the desirability of establishing in each maritime country a number of coast stations with a permanent service adequate for the needs of navigation."

The new regulations contain several provisions intended to render more effective the service of wireless telegraphy in cases of distress at sea. Ships will in future be required to provide an auxiliary source of power able to work the wireless apparatus for at least six hours. This emergency installation must be placed in as secure a position as possible, and must be entirely self-contained, so that an accident to the ship which stops the working of the ship's engines need not affect the wireless apparatus. Steps have also been taken to lessen the danger of distress calls going unheard by laying down rules as to attendance on the wireless apparatus in various classes of ships. On ships of the first class a premanent watch will be required, and in this case two fully-qualified operators at least must be carried. On ships of the second class, where a permanent watch is not considered practicable, the operator must listen during the first 10 minutes of every hour. In the smallest ships (fishing boats, &c.), no regular periods of watch are prescribed. Each Government in giving a license to carry wireless apparatus will determine in which of these three classes it is to be placed.

Rules have also been made for both ships and shore stations to suspend work and to listen at the end of each quarter of an hour in cases where it is likely that distress calls might otherwise not be heard. To prevent confusion the ship in distress will in future have control over the wireless working of all stations in its vicinity, while the operators on every ship are now specifically placed under the authority of the captain. Provision has been made for giving priority of transmission to weather reports from ships and for keeping coast stations supplied with weather forecasts for communication to ships on demand.

In order to prevent confusion in working, the regulations adopted at the Berlin Conference required ships to communicate with the nearest shore station. Various proposals were made for modifying this regulation so as to allow communication between a ship and a station which is not the nearest. These proposals gave rise to considerable discussion, and a regulation was finally adopted which permits such communications provided that a special specified wave length is used for the purpose, but at the same time limits this exceptional arrangement to the case of communications exchanged between a ship and a shore station in the country to which the ship belongs.

Numerous other changes were made in the regulations, with the object of promoting the smooth and expeditious working of the service. In this connection it may be mentioned that all the countries concerned have now agreed that all ships should be under the obligation to intercommunicate with one another, irrespective of the system of radio-telegraphy employed. It was decided that it would be premature to attempt to lay down regulations for the long distance between land stations, and it was expressly laid down that each country remains free to organise services of this nature as it thinks best, the only principles laid down being that interference between different stations must be avoided as far as possible, and that differences in the system of wireless telegraphy employed must not be a basis for refusing intercommunication.

The American delegation conveyed an invitation from their Government (subject to the necessary vote of Congress) to hold the next conference in Washington. This invitation was unanimously accepted, and 1917 was fixed as the date at which the next conference will be held.

The Simplon Tunnel.—The proposal, which was recently made, to widen the Simplon tunnel has, we learn, been rejected by the Federal Government in favour of the original plan of having a second gallery. For this enterprise, the cost of which is estimated at a sum of somewhere about 35,000,000 f., it is reported that seven firms have tendered, and that negotiations have now been opened with Messrs. Brandau.

Proposed Memorial to Thomas Newcomen.—A proposal is on foot for the purpose of instituting a memorial of the famous engineer and inventor, Thomas Newcomen, who was the first (at least in England) to work out the idea of a piston in his atmospheric engine, being the first piece of mechanism in which steam was used with practical success. This invention was at once utilised for pumping water out of the Cornish mines, and for this and other purposes proved highly efficient, being also the pioneer of our present locomotive and stationary steam engines. As this well-known worthy was a resident and native of Dartmouth, having been born there in 1663, it is proposed that a memorial should have its site in this borough. Incidentally it may be mentioned that the present year is the bi-centenary of Newcomen's invention. The representatives of Dartmouth, municipal and otherwise, feel justified in making an appeal for aid, external and local, towards a memorial of one to whom, as the pioneer of steam utilisation in England, we are all more or less indebted in every ministration of art and science, for countless necessities and conveniences of our every-day life, and yet who has hitherto been so sadly and strangely neglected. As regards the form the memorial shall take, various schemes have been proposed, but the adoption of one or more of these must naturally depend on the response made to this appeal. Contributions may be sent to the hon. treasurer (Mr. A. R. Gregory), manager of Lloyds Bank, Dartmouth.

INDUSTRIAL AND TRADE NOTES.

Cleveland Blastfurnacemen's Wages.—The average net selling price of No. 3 G.M.B. Cleveland pig iron for the months of April, May, and June, has been certified at 50s. 0·13d. as compared with 48s. 4·16d. for the first quarter of the year. This means an advance of blastfurnacemen's wages on the North-East Coast of 2·25 per cent., which raises wages from 20·25 per cent. over the standard to 22·50 per cent. above the standard.

Nationalisation of the Mines. — At a meeting of the executive of the Miners' Federation of Great Britain, held in London on the 5th inst., a committee was appointed to draft a Bill for the nationalisation of the mines of the country, and it was further decided to initiate an active propaganda in all mining districts and industrial centres, to present the case of mines nationalisation from the point of view of the mining industry, and also from the point of view of British trade generally.

Sternol Oil Testing Machine.—We have received from the Stern Sonneborn Oil Company, Ltd., Royal London House, Finsbury Square, London, E.C., a descriptive pamphlet, giving particulars of the Sternol Oil Testing Machine, which, it is claimed, is an important step in the scientific testing of oils, as by its means comparative values of lubricating and cylinder oils and greases can be established under actual working conditions at the actual temperature and pressure the lubricants undergo in practical use.

Personal.—Mr. Tom Westgarth, of Middlesbrough, the joint managing director of Messrs. Richardsons, Westgarth, & Co., Ltd., engine builders, of Hartlepool, Middlesbrough, and Sunderland, has, we understand, resigned his position, but will retain a seat on the board. Mr. D. B. Morison, who will now be sole managing director of the company, has appointed Mr. E. Hall Brown to be general manager of the Middlesbrough works. Mr. Hall-Brown is well known in marine engineering circles, and is at present president of the Institution of Engineers and Shipbuilders in Scotland.

Prices per Ton of Cleveland Iron, January to June, 1912.



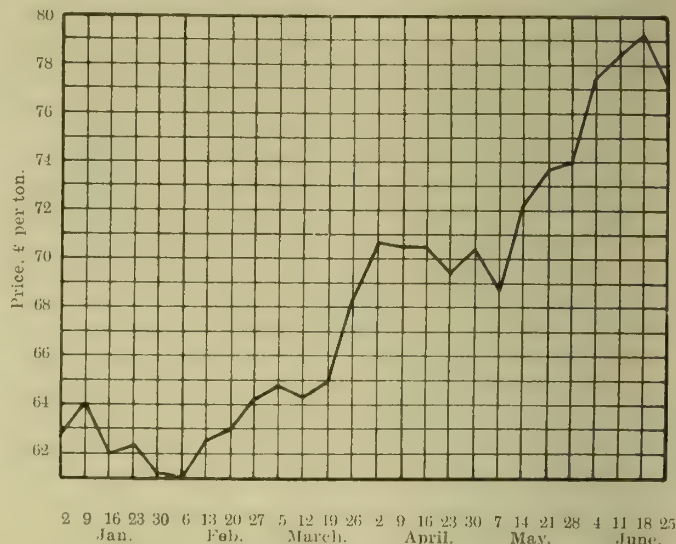
Coalite, Ltd.—Mr. A. M. H. Walrond, the chairman, presiding at the ordinary general meeting of Coalite, Ltd., held in London, on the 4th inst., stated that the capital of the company had been increased by 81,100 shares, and that they had issued a further 410 shares at an average price of £1. 8s. per share during the current year. Referring to the expenditure and the receipts, the chairman said that the total year's profit amounted to £2,084, which, added to the old balance, made a sum of £16,077 to be carried forward. A good deal had been done to pay off old creditors. The report was adopted.

Demarcation Dispute at Barrow Shipyard.—During the past week a demarcation dispute occurred at the Barrow Shipyard of Messrs. Vickers, Ltd., between fitters and boilermakers respecting the caulking of certain parts of the conning tower and the barbettes, &c., on H.M.S. "Lion." The fitters claimed that it was their job, and as a consequence some 2,300 men were rendered idle. The dispute was settled the day after its commencement, Messrs. Vickers agreeing that the caulkers' work on the disputed job should be included in the duties of boilermakers, and that this arrangement should form part of the boilermakers' agreement with the firm

Immingham Dock Extensions. — When the Immingham Deep Water Dock, which is to be opened by His Majesty the King, on the 22nd inst., was designed, land was acquired for the purpose of extensions, provision being made for the construction of four arms extending from the central basin of the dock, and each capable of giving an increased water space of some 10 acres. Now that the main basin and one arm have been completed, the rush of traffic is so great that the Dock Company is contemplating proceeding at once with the construction of the south arm. It is expected that the work will be begun at once, and it will take between two and three years to complete.

Effect of Miners' Strike on Railway Receipts.—The official returns of the 51 principal railways in the United Kingdom for the 26 weeks (December 31st to June 30th) amounted to £52,712,226, a decrease of £2,627,325 on the corresponding period of last year.

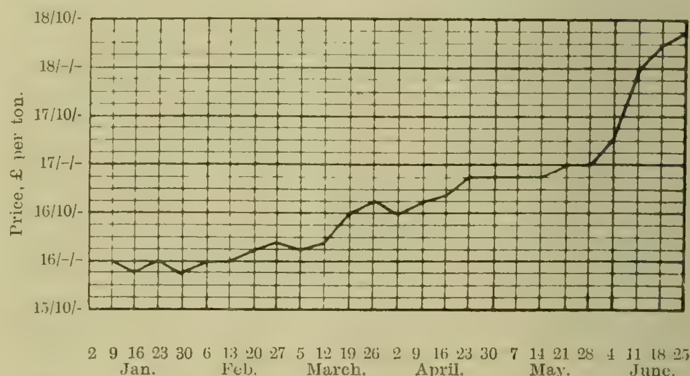
Prices per Ton of Standard Copper, January to June, 1912.



This decrease is entirely due to the miners' strike of last March. For the nine weeks ended March 3rd, there was an aggregate increase of £345,273. In the following eight weeks, however, this increase was wiped out and a decrease was shown of £3,856,064, which, in the course of the last nine weeks of the half-year, was reduced by £1,238,739, indicating that although the strike seriously interfered with business, its effects have now been largely overcome. The traffics now being reported are excellent, and the railways may look forward with confidence that the next half-year will greatly improve their position.

A Gas-engined Vessel.—Messrs. Napier & Miller, Old Kilpatrick, launched a few days ago the auxiliary surveying vessel "Y Ddraig Goch," which they have built for Mr. Godfrey H. Williams, of Aberpergwm, to the specification of Mr. William Gray, London. The vessel is 200ft. in length on the water line, 38ft. in breadth, and 21ft. 6in. in depth. The propelling machinery consists of a single-screw gas engine with six cylinders, of about 225 h.p. There is a suction gas producer with washer complete, anthracite coal being used. The vessel is fitted with a Bevis reversing propeller. An auxiliary gas motor drives a dynamo supplying the current throughout the ship for working the various pumps, the windlass, and the capstan. There is large bunker capacity, which will enable the vessel to make a cruise practically round the world without refilling her bunkers.

Prices per Ton of English Lead, January to June, 1912.

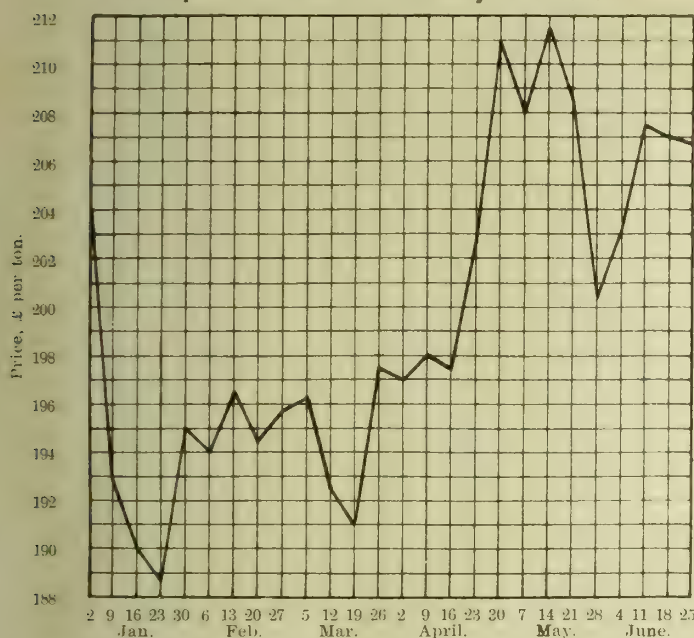


Trade Circulars.—Messrs. Siemens Bros., Ltd., Upper Thames Street, London, E.C., send us a copy of a descriptive pamphlet, dealing with their G5 watt hour meter, which consists of a small electric motor, the magnetic field of which is created by series current coils, while the shunt current flowing through the armature is limited by the resistance in series with the armature. The

readings of the meter are proportional to the current flowing through the series coils and the supply voltage. The brake element consists of an aluminium brake disc and rotates between the poles of a permanent magnet. The meter, it is claimed, is particularly suitable for export work.—The British Anti-Vibration and Noise Company, 105, St. Vincent Street Glasgow, send a pamphlet descriptive of their special methods of deadening vibration and noise arising from the running of machinery, gas engines, &c. The devices are of various kinds which experience has shown to be best adapted to deal most effectively with the particular troubles.

Industrial Census, 1913.—The Second Census of Production, under the Census of Production Act, 1906, will be taken next year in respect of production carried on in the present year. The schedules to be issued to manufacturers will, in the main, cover the same ground as those of the First Census, but the instructions have been simplified somewhat, and the majority of the schedules reduced from eight pages to four pages. In certain schedules particulars will be required of the total make of important semi-manufactured products, such as yarns, pig iron, steel ingots, &c., whether further worked up by the makers or not. By arrangement with the Home Office the particulars of the numbers of persons employed will also serve as the ordinary Return required for 1912 under Section 130 of the Factory Act, and manufacturers will thus be saved the trouble of making two separate Returns. Small firms employing not more than five persons besides the employer, on making a declaration to that effect on the schedules issued to them, will be exempted from the requirement to furnish Returns. At the present time the schedules are being issued in draft to Chambers of Commerce and Trade Associations in order to afford them an opportunity for the consideration of the details of the information required before these are finally settled. The schedules on which manufacturers will be required to make their Returns will not be sent out until the beginning of next year.

Prices per Ton of Block Tin, January to June, 1912.

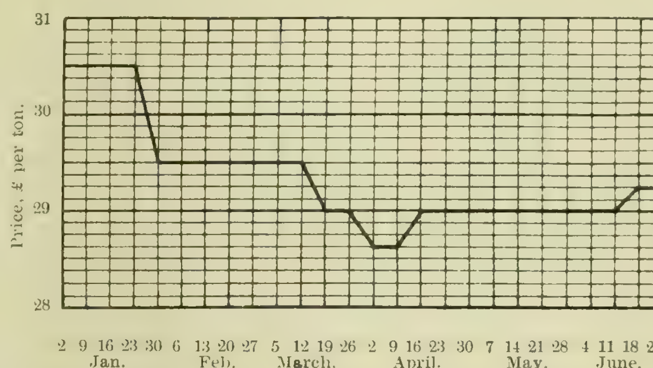


The Krupp Company.—A report just issued by the Essen Chamber of Commerce gives some particulars regarding the present equipment of the Krupp Company. The cast steel works at Essen comprise about 60 departments, containing 7,700 machine tools, &c., 16 rolling mills, 164 steam hammers from 100 to 10,000 kilos, 139 hydraulic presses, 539 steam engines from 2 h.p. to 7,000 h.p., and representing in the aggregate 95,920 h.p., 3,392 electric motors representing altogether 62,565 h.p., 1,177 cranes, &c., up to 150,000 kilos carrying capacity, and aggregating 12,694,350 kilos carrying capacity. The coal mines of the company produced 2,600,293 tons last year. The water consumption of the concern was 18,818,509 cubic metres, about the same as the total consumption in Bochum, a town of about 120,000 inhabitants. There are seven electricity works in connection with the Essen plant, generating last year 54,662,200 kw. hours. There are three shooting ranges for testing ordnance, and last year 1,512 guns were tried, 34,600 shots being fired. The total number of workpeople employed at the various works is given as 69,950. Of these 37,853 are in the cast-steel works and shooting ranges in Essen, 6,346 at the Friedrich Alfred smelting works, Rheinhausen, 980 at the Annen steel works, 1,127 at the Gruson works, Magdeburg, 4,923 at the Germania shipyard, Kiel, 10,008 at the various coalfields, 853 at the Rhenish smelting works, and 4,507 at the iron ore mines.

Standardisation of Automobile Parts.—A conference of engineers and representatives of the various institutions representing the motor car industry, convened by the Engineering Standards Committee, to consider the advisability of the standardisation of automobile parts, was held on Friday, June 28th, in London, Sir John Wolfe Barry, K.C.B., chairman of the Engineering Standards Committee, being in the chair. A resolution was passed that the standardisation of automobile parts and the preparation of standard specifications for the material used therein were desirable. It was decided to recommend to the main Engineering Standards Committee that those invited to the conference be formed into a sectional committee to deal with the matter with power to add to their numbers. It was understood that the sectional committee would have power to form sub committees and to co opt members having expert knowledge of the particular branches of the subject to be dealt with. A printed list of matters which it was suggested might receive attention was submitted to the conference, but it was decided that the reference to the committee ought not to be confined to these, but that it should be open to discuss such matters as from time to time were brought forward for consideration. It was suggested that each of the various bodies appointing delegates to the committee should be asked to draw up a list of the subjects it desired should receive attention, so that the committee might have these before it when commencing work.

New Dredger for Burma.—Messrs. William Simons & Co., Renfrew, launched, on the 2nd inst., the dredger "Lees," which they have built to the order of the Indian Government for the improvement of the waterways in Burma. The dredger is of the "Simons" suction reclamation type, and has been specially designed and constructed under the direction of Prof. J. H. Biles. The "Lees" is a twin screw light-draught cutter dredger, and she will work in conjunction with a floating pipe line and terminal pontoon, arranged for delivering dredged material over river or canal banks for land reclamation. The dredging pump is driven by an independent set of triple expansion engines, and the suction pipe is carried on a frame fitted in at the forward part of the vessel. The lower end of the suction frame is fitted with a steel spiral rotary cutter, driven by cast steel machine-cut gearing from a set of horizontal compound engines placed on deck. Independent steam hoist gear is provided for controlling the suction frame, and very powerful manœuvring winches are placed at each end of the vessel. The dredger is propelled by twin screws, each driven by triple expansion engines. Steam is supplied by two cylindrical multi-tubular boilers, constructed for a working pressure of 160lbs. The boilers are fitted with Howden's forced draught for burning Indian fuel. A repair shop with electrically driven machine tools capable of undertaking minor repairs is fitted on board.

Prices per Ton of Silesian Zinc Sheets, January to June, 1912.



Durham Collieries Electric Power Company.—At the ordinary general meeting of this company, held in London on the 4th inst., Mr. A. W. Tait said the company had again made a loss. In consequence of the report which the directors obtained from an independent electrical engineer, the prospects were considered so unsatisfactory that the position was placed before the debenture stock-holders. An endeavour was made to try and arrive at some settlement of the situation by means of getting an amelioration of the conditions under the contracts, but that was found impossible. The directors afterwards entered into negotiations with the Newcastle-on-Tyne company for the sale of the company's undertaking, and those negotiations looked as if they would ultimately be successful. He was afraid, however, that the negotiations, even if they were concluded, would mean that the property would be sold at a price which would leave nothing whatever for the shareholders; in fact, there would be a substantial loss to the debenture shareholders. The report of the independent expert showed that not only was the position unsatisfactory at the moment, but that as the load grew there was no great prospect of better results.

This was due, he thought, to the mistake made originally with regard to the load factor in working the collieries. At the time the feeling was that the load factor would be very much higher than it had actually turned out to be. It was, therefore, proposed that the company should be voluntarily wound up. The report was adopted, and at an extraordinary meeting subsequently held a resolution was passed voluntarily winding up the company.

World's Shipping.—The statistical tables prepared by Lloyd's Register of British and Foreign Shipping for the 1912-1913 edition of their Register Book show that during 1911 the number of vessels of 100 tons and upwards (excluding yachts) built throughout the world was 1,189 vessels of 2,405,681 tons. Of these 628 of 1,671,102 tons were constructed in the United Kingdom. The total number of all classes of vessels built in the United Kingdom was 768 of 1,250,810 tons. The additions made to the Register of the United Kingdom—including vessels bought from foreign countries and transferred from the British Colonies, as well as new vessels built at home and abroad—amounted to 1,005 of 1,356,251 tons. The removals from the Register during the same period were 1,015 vessels of 1,018,034 tons. The ruslt of the year's additions and deductions therefore is a decrease of 10 in the number of vessels registered, but an increase of 338,217 in the aggregate gross tonnage. The total number of vessels of 100 tons gross and upwards belonging to the several maritime countries of the world as recorded in the Register Book is 30,316 of 44,600,677 tons. Of these 11,444 vessels of 19,874,360 tons are British—9,279 vessels of 18,213,620 tons belonging to the United Kingdom and 2,165 of 1,660,740 tons to the Colonies. America has the next largest tonnage, the number of vessels being 3,442 and the tonnage 5,258,487. Germany has 2,213 vessels of 4,628,983 tons, Norway 2,132 vessels of 2,292,596 tons, France 1,491 vessels of 2,052,518 tons, Italy 1,090 vessels of 1,398,582 tons, Japan 960 vessels of 1,344,991 tons, and Holland 701 vessels of 1,129,906 tons. The number of vessels classed with Lloyd's Register is 10,445.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Apparatus for raising or forcing liquids. Humphrey & Rusdell. 11818.
Apparatus for raising or forcing liquids and compressing gases. Humphrey. 12055.
Steam turbine. Vereinigte Dampfturbinen-Ges. 14163.
Starting devices for explosion engines. Adams, and Adams Manufacturing Company. 14204.
Valves or internal combustion engines. Berlize. 14261.
Rotary engine. Dugins. 14491.
Steam generators. Justice. 14496.
Turret-slide mechanism for turret lathes. Potter. 14596.
Method of utilising surplus compressed air in internal combustion motors. Daimler Motoren Ges. 14598.
Recovery of sulphur from gases. Teed, Sulman, & Picard. 14628.
Bright annealing of non-ferrous metals. Barker. 14648.
Car coupling mechanism. Willison. 14736.
Change speed and reversing gears. Wirtz. 15006.
Mechanical ore roasting furnaces. Harris. 16583.
Gas turbines. Baxter. 16613.
Brakes for railway wagons. Oxley & Parker. 16791.
Mechanical ore roasting furnaces. Harris. 17847.
Explosion turbine. Kutschinski. 18055.
Chain gearing. Craig, Napier, and Coventry Chain Company. 18380.
Liquid fuel spraying devices. Babcock & Wilcox, Ltd. 18711.
Valves. Pankhurst. 20134.
Disc milling cutters or circular saws. Zweng. 20154.
Starting systems for internal-combustion engines. Bell. 20376 and 20736.
Exhaust silencers. Schelle & Co. 22939.
Apparatus for smelting metals. Hoveler. 23117.
Apparatus for signalling on trains and for stopping trains. Snyers. 23999.
Self-locking nuts. Asbury. 24583.
Four-stroke cycle engines. Kruk. 24665.
Valve mechanism for internal combustion engines. Coffin. 25907.
Rotary or turbine engines. Stevenson. 26617.
Mechanism for converting rotary motion into reciprocating motion. Justice. 26639.
Combined drill and countersink. Ullrich. 26907.
Means for injecting and vaporising liquid fuel in internal combustion engines. Peterson, and Storebro Aktiebolag. 26917.
Pinions for sliding wheel gears. Birkigt. 27040.
Extraction of metals from their ores. Leslie. 28235.
Crucibles or melting pots. Morgan Crucible Company, and Harvey. 28269.
Two-stroke explosion engines with revolving cylinders. Léger. 28510.
Coupling apparatus for railway vehicles. Kuscielek & Rothstein. 28850.

1912.

Gas washer. Aminoff. 126.
Signalling device for railways. Sander, Volz, & Nippel. 1265.
Evaporating and distilling plant. Weir. 2813.
Valve gear of internal combustion engines. Haffenden & Kynoch, Ltd. 3700.
Shaft bearings of rotary pumps. Gaede. 4166.
Expansible pulleys. Caldwell. 4750.
Water-cooled internal-combustion engines. Hesselman. 5348.
Internal-combustion engines. Twombly. 5789.
Pyrometers. Rogers. 6364.
Pistons. Rainforth, and D. Napier & Son, Ltd. 6826.
Centrifugal fans or blowers. Frame. 7149.
Process for hardening low carbon steel. Geb. Schubert. 7558.
Blade wheel pumps. Eisemann & Lehne. 8104.
Fluid pressure brakes. Donovan. 8153.
Steam generators. Justice. 8880.
Screw propellers. Simon. 9582.
Arrangement for diminishing clearance losses in turbines and pumps. Holzer. 10179.

ELECTRICAL, 1911.

Electrically operated reversing gear. Brüll. 9255.
Telephone systems. Dicker. 9577.
Electrical servo and tele motors and their modes of application. Rottenburg. 14175.
Magneto generating machines for lighting and ignition purposes on motor vehicles. Vaughan. 14360.
Electric transportation systems. Vaughan. 14505.
Storage battery plates. Lake. 14938.
Manufacture of electric steel. Stobie. 17179.
Visible electrical signals in connection with colliery winding engines. Charlton & Smith. 17430.
Double pole electrical switches. Midland Electric Manufacturing Company, and Barber. 20311.
Magnetic tachometers. Thompson. 25488.

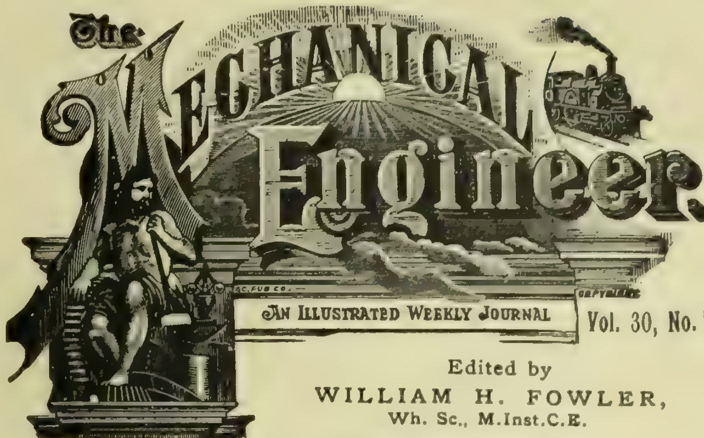
1912.

Arc lamps. Siemens Bros. Dynamo Works, Ltd. 955.
Electric telegraphy. Muirhead, and Muirhead & Co. 2049.
Electrolytic apparatus. Hazard Flamand. 2124.
Arrangements for accelerating the variation of a magnetic field in dynamos. Allmänna Svenska Elektriska Aktiebolaget. 4283.
Method of suspending electric conductors between supports. Pohlig Akt. Ges., and Ellingen. 4779.
Multiple arc lamps. Ges. fur Maschinen und Metall Industrie. 5301.
Telegraph transmitting machines. Del Valle Atiles. 7290.
Electric circuit breakers. Fagerlund. 9647.
Continuous current electric meters. Siemens Schuckertwerke Ges. 9823.

METAL QUOTATIONS.

TUESDAY, JULY 9TH.

Aluminium ingot	75/- per cwt.
,, wire, according to sizes, &c. ......from	102/- ,,
,, sheets ,, ,, ... ,,	120/- ,,
Antimony .... £27/10/- to	£28/-/- per ton
Brass, rolled	9¼d. per lb.
,, tubes (brazed)	11¾d. ,,
,, ,, (solid drawn)	10d. ,,
,, ,, wire	9¼d. ,,
Copper, Standard	£72/5/- per ton.
Iron, Cleveland	56/7½ ,,
,, Scotch	62/7½ ,,
Lead, English	£18/17/6 ,,
,, Foreign (soft)	£18/10/- ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£8/10/- per bottle
Silver	28d. per oz.
Spelter	£25/17/6 per ton.
Tin, block	£202/-/- ,,
Tin plates	14/7½ ,,
Zinc sheets (Silesian)	£29/5/- ,,
,, (Stettin; Vieille Montagne)	£29/7/6 ,,



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Edited by
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The Illumination of Workshops.

THE proper lighting of a workroom is of importance both to workpeople and employers. To the former because, in many cases, where diligent use of the eyesight is necessary to perform their duties, bad lighting may cause serious injury, and to the latter because anything which interferes with the discharge of workmen's duties reduces industrial efficiency. The subject has not in the past received the attention it deserved, and the more careful study bestowed on it during recent years shows that in many instances illumination is ineffective not from absence of light so much as from improper use of it, and general ignorance of the principles which should govern its distribution. For this reason the special report on the subject of Factory Lighting, by Mr. D. R. Wilson, which has been issued in the annual report of H.M. Inspector of Factories, is deserving of study, and though it deals more particularly with the lighting of textile mills, the principles which apply to them apply equally to all workshops where clear and comfortable vision is required. The illumination of a room may be regarded from two points of view, according as it is desired for the general lighting of the area as a whole, or of a small circumscribed area where some specific work is being carried on more or less continuously, and practically there are always two kinds of light to be considered, viz., daylight and artificial. The principal distinction between the two consists in the variability of the former, which differs not only with the seasons, but from hour to hour; and a further distinction lies in the fact that whereas we can with artificial light regulate its exact position and quantity to suit the convenience of the work, the source of daylight is limited to the boundary walls of the building or to the roof. The latter is, of course, the most efficient area where it is available, but obviously that can only be on a specially-arranged upper floor or ground floor shed. In the bulk of cases window space in the side walls is the only source,

and the amount of light that can enter often varies considerably even in the same structure, owing to the presence of adjacent buildings. Ground floors are frequently very defective on this account, apart from deficient window area, which, to secure efficient daylight illumination, should relatively to the floor area amount to at least 10 per cent., and be as symmetrically arranged as possible to secure uniform diffusion. To this end the nature of the walls plays a more important part than is generally thought. They should be of a light tint, and of a matt surface to increase diffusion. By paying attention to this detail the illumination may sometimes be trebled or even quadrupled. As an example, Mr. Wilson quotes an observation of a linen-weaving shed where the illumination intensity in the centre was 9·7 foot-candles, whereas at a distance of 3ft. from whitewashed walls it was 13·5 foot-candles, showing an increase of 50 per cent. due to reflected light from the wall. It is, however, with artificial lighting that most scope is afforded for good and bad arrangements, and where errors most frequently occur. The main principles to be observed are: (1) The light should be adequate; (2) it should not cause glare effects; (3) it should not produce troublesome shadows. The question of adequacy depends on a number of considerations, such as nature of work, fineness and colour of material, &c., and is not one on which special rules can be formulated, as circumstances differ widely. The work may be of a nature which demands close application to a small area, or may only require general supervision over a given process, while individual eyesight as well as work may vary. Obviously, however, dark objects require more illumination than light ones, and where colour variations occur the same should permit of adjustment, and this can usually be simply obtained by allowing a few feet of flexibility in the distance of the source. Glare effects, while readily understood in a general way are less easy to define, but the definitions put forward by Prof. L. Weber, of Kiel, are probably on the whole the most practicable. According to these a lighting system is glaring: (*a*) If the ratio of the "intrinsic brilliancy"* of the source of light to that of illuminated surfaces exceeds 100; or (*b*) if the absolute intrinsic brilliancy exceeds that of an open candle flame—which is about 2·5 candles per square inch; (*c*) if the angle between the line of vision when directed on the work and the line from the eye to the source of light is less than about 30°; (*d*) when the apparent area of the illuminating source subtends an angle of more than 5° at the eye.

To avoid glare, therefore, the important points to note are the position of the light unit, and its efficient shading. In most instances the angle of glare, which Prof. Weber fixes at 30°, can be easily avoided by raising the light unit sufficiently high. Some sacrifice of light is, of course, entailed in this, but if a few inches will, as is often the case, eliminate "glare" the diminution in intensity is inappreciable. If the light, which of course varies as the square of the distance from the illuminated object, and as the cosine of the angle of incidence, will not permit of this, then the only remedy is efficient shading, and when this is necessary care should be taken to make the shade sufficiently deep to afford complete protection to the eyes.

Independently of this, shades are often of convenience to concentrate light on the area immediately beneath them, and the extent to which this occurs is illustrated by observations in a cloth factory, where the illumination intensity of electric metallic filament glow lamps at points 2ft. 3in. vertically below the lamps was found to be 1·2 and 2·5 foot-candles without shade and 3·1 and 7·0 foot-candles when fitted with prismatic shades. The nature of the shade, it may be further observed, influences the radial distribution of the light, and should therefore be selected with a view to the particular result desired. A common example of failure in this respect is often afforded when carbon filament lamps are replaced with electric filament lamps. In the latter the light is thrown out more horizontally, and therefore to obtain the full benefit of the change new shades should be provided.

With artificial light troubles from shadows are more serious than with daylight, and in dealing with them two qualities are to be noted, viz., position and depth, the former depending on the position of the "local" light unit, and the latter on the general illumination of the neighbourhood. To avoid trouble as much as possible the unit serving each area should be so placed that the light falls from the side, or, better, over the shoulder of the worker. If the lamp is in front with the machine between, these neighbouring lights should have access to the work to neutralise the shadow as far as possible. The suggestion seems obvious, but it is not always observed, and inefficient illumination often arises in consequence. Another common failing is the placing of lights so that they cast the worker's own shadow on his work. This is doubly annoying, because it not only cuts off light but baulks the worker by its movements. A comparison of various kinds of artificial light opens up of course big questions, and the rival merits of gas and electricity is not one into which we purpose to enter here at any length, suffice it that from a sanitary point of view the superiority of electricity as an illuminant is universally admitted, and though, as regards efficiency, incandescent gas compares favourably and even advantageously with it in some instances, nothing can be said in favour of flat-flamed gas burners as sources of illumination, though they are still extensively used. They not only flicker and evolve much heat, besides vitiating the air, but they use 12 to 15 times as much gas per candle-hour as other gas lighting systems.

* *i.e.* the brightness of a surface emitting light expressed in terms of candle power per square inch area of surface.

THE SELF-DEMAGNETISATION OF STEEL.

A PAPER by Messrs. S. W. J. Smith and J. Guild on this subject was read at a recent meeting of the Physical Society of London. The constituents, iron and iron carbide, were, the authors stated, easily traceable in annealed steel, owing to the differences between their magnetic properties. The ferromagnetic transition point of the carbide was about 500° C. lower than that of the iron. The carbide was also magnetically harder at ordinary temperatures and possessed greater coercive force, although, like iron, it was magnetically very soft at temperatures near the transition point. In consequence of these facts, the effect of heat upon the residual magnetism of an annealed steel rod was peculiar and at first sight mysterious. As the temperature rose the residual magnetism fell continuously until it became zero in the neighbourhood of 200° C. It then changed sign and reached a maximum negative value at about 220° C. Beyond this, the negative magnetisation decreased slowly, and finally became imperceptible between 700° C. and 800° C. If the rod was cooled from 800° C. it remained without perceptible polarity as the temperature fell; but if the heating was interrupted before the whole of the residual magnetism was destroyed the behaviour on cooling was quite different. Thus, to quote one case, the rod was heated until, at 600° C., the residual intensity of magnetisation was about —0·5. On cooling the intensity increased to a maximum negative value of about —1·6 at about 245° C. Then the magnetisation began to fall, reached zero at about 210° C., became positive and, finally, was about + 15·5 at the air temperature. An explanation of these and other results which were described was given in the paper, in which it was shown that the residual magnetism of short annealed steel rods was determined by the retentivity of the carbide, and that the residual polarity of the iron was negative. The iron may thus be said to contribute less than nothing to the residual magnetism of the rods.

BOOK REVIEWS.

Text-book on Motor-car Engineering. Vol. I., Construction. By Grahame Clarke, A.M.Inst.C.E., Member of the Institute of Automobile Engineers, Lecturer on Motor-car Engineering, Polytechnic School of Engineering, Regent Street, W. 8¾in. by 6in., 437 pages. London: Constable & Co., Ltd. Price 8s. 6d. net.

Several books have been published professing to deal with the mechanical principles and detail of motor-car engineering, but most of those which have come under our notice have been rather in the nature of glorified makers' catalogues, with a profusion of half-tone illustrations which tell little or nothing. This one specially appeals to us by contrast. It bears the stamp of thoroughness all through. It deals with principles of construction and details of arrangement, with sectional views, not outside pictures; in a word, with solid matter, not veneer. It is what a text-book should be and what the engineer or the student who seeks scientific explanation and comparisons of the relative advantages of different arrangements wants. There has been a need for a book of this kind, and we have pleasure in commending it not only to the student who seeks information on the thermodynamic and constructional problems of this class of internal-combustion engines and its mountings, but also to the makers of them. They will find much that will interest and in many cases instruct them.

* * *

The Dynamics of Mechanical Flight, by Sir G. Greenhill. Lectures delivered at the Imperial College of Science, March, 1910-11. 9in. by 6in.; 122 pp. London: Constable & Co. 8vo. Price 8s. 6d. net.

Apart from a brief introduction, the subject matter of this little book, as might be expected, is almost entirely mathematical, and intended for the delectation of the advanced scientific student of the subject. The circle of readers will necessarily be a small one, but it is on them that future progress in aerial flight will now to a great extent depend, and by this select audience we doubt not the problems presented and discussed will be appreciated. The subject matter is divided into six chapters; the first deals with general principles of flight, light, and drift; the second with general solutions of the problems relating to thrust, and centre of pressure in an aeroplane; the third discusses the Helmholtz-Kerchoff theory of a discontinuous stream line; the fourth is devoted mainly to gyroscopic actions; the fifth to the action of the screw propeller; while the last chapter is a brief outline of the pneumatic principles of an airship.

* * *

Theory of Structures, by Arthur Morley, M.Sc., Professor of Engineering, University College, Nottingham. London: Longmans, Green, & Co. 9in. by 6in.; 574 pp. Price 7s. 6d. net.

The strength and design of structures is a subject on which a great deal has been written, and the fundamental principles, so far as they can be applied or defined, are so generally recognised that within these limits there is not much room for an author's personality or for original treatment, but when we depart from the most elementary forms exact mathematical analyses of stresses have rapidly to give way to conventional treatment based more or less on experiment and practical experience, and it is in this direction scope is best afforded for the exercise of an author's abilities as guide and counsellor to students and in which this work more particularly excels. Nothing helps more to a firm grasp of this feature of structural design than the working out of examples, and the carefully selected ones offered to the reader constitute an important feature of the book. To those who already possess the author's work on "Strength of Materials" the early chapters will seem familiar and is accounted for, we are frankly told in the preface, by the fact that a considerable amount of the matter in seven chapters out of the first nine is taken, without great modification, from that earlier work, to which the present volume is intended to form a companion. The appropriation, it is true, makes the present work self-contained, though it rather suggests an amount of overlapping which, however advantageous to the book publisher, is a bit rough on the purchaser. But we would not emphasize this point unduly in view of the excellence of the matter, the way in which it is presented, and its relative cheapness compared with works of a similar character. The matter is clearly written, solidly packed, well printed, and copiously illustrated.

BOOKS RECEIVED.

Manuals of Safety. No. 3, Foundry Practice. Published by the American Museum of Safety, New York. Price 25 cents.

How to Drive a Motor Cycle. London: Percival, Marshall. Price 6d. net.

A Primer on Alternating Currents, by W. G. Rhodes, D.Sc., Head of Electrical Engineering Department, Royal Technical Institute, Salford. London: Longmans, Green, & Co. Price 2s. 6d. net.

A Short Course on the Testing of Electrical Machinery for Non-Electrical Students, by J. H. Morecroft, Assistant Professor, and F. H. Hehre, Instructor in Electrical Engineering, Columbia University. London: Constable & Co. 6s. net.

NEW OPEN-HEARTH FURNACE DESIGNS.

In "The Iron Age" of June 27th, Mr. H. F. Miller, jun., of the Verona Steel Castings Company, describes some modifications in the design of open-hearth furnaces which he claims are an improvement on existing arrangements. The present open-hearth furnaces are, he states, so designed that the fuel has, as its source of combustion, an overlying layer of preheated air. This means that the bottom of the layer of gas is not supplied with enough oxygen to completely burn it, and as a result the gas does not develop the temperature it should attain next to the bath, where it is needed. The air is overhead for two reasons: (1) it acts as an insulator between the roof and the flame; (2) the air being heavier, presses the flame down on the bath more or less, thus making the flame do its work by contact rather than by radiation.

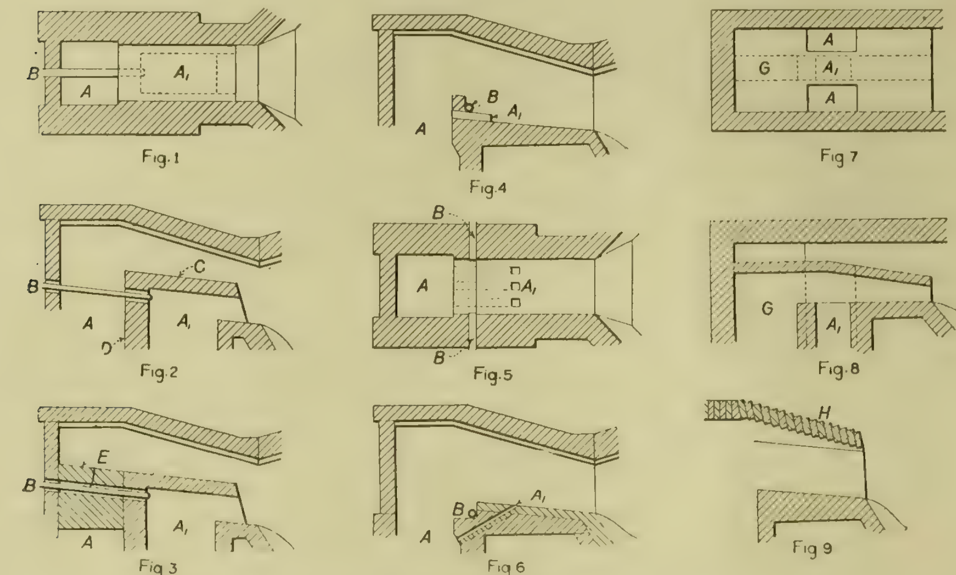
Departures in design of open-hearth furnaces have been held in check by two main considerations, namely, the gas cost and the brick cost, and the problem of making the two costs dovetail efficiently is a source of ceaseless worry to the open-hearth furnace men. In the furnace of the open-port type the combustion and control of the gas is effected almost wholly by the width of the port. If the port is made narrow the gas layer increases in depth. This thick layer of gas acts as an insulator of itself, preventing the bottom gas layers from combining with the overhead layers of the air. Thus a high gas cost is attained by poor combustion. The control of the gas in this case is excellent and the brick cost low. On the other hand, if the port is widened so that the gas layer becomes thinner, the opportunity for combustion is increased, but the control of the gas is lost, resulting in a high brick cost due to burning. The producer gas type is affected by a loss of control of gas as the rings in the arch of the gas port drop down or burn back. But here the poor combustion of the lower part of the gas layer by the overhead layers of air is more definitely emphasized than it is in the open-port type, because of a greater distance from the source of combustion.

Both of the above-mentioned types are used when oil is employed as fuel. Indeed there seems to have been no special effort made to design a furnace especially for oil or liquid fuel. When oil is used in the two types, the point of the burner is projected across the uptake, for the combustion is so perfect when the point of the burner is drawn back off the air uptake that the intense heat created melts the roof and bottom of the port. The author has actually caused magnesite to melt under these conditions.

The logical questions that present themselves now are: (1) if the narrow port in Fig. 1 gives such excellent control of the flame, is there not some simple and efficient means by which good combustion can be obtained without sacrificing the control of the flame? (2) and is there not some simple construction that will lengthen the life of the gas ports in the producer gas furnace without resorting to troublesome water-cooling devices, and at the same time providing for a far better combustion? (3) also, if such an intense heat can be created by discharging fuel across the uptake, cannot some form of

construction be devised wherewith the flame can be made as hot unattended by evil effects to the roof and port?

Each of these questions has been solved by utilising the same principle with a design suitable to the fuel. The principle of a wide port—good combustion and poor control of the flame—was demonstrated when one of our furnaces was built, which made only 187 heats. The average time was 6 hours 30 minutes on cold charges. The high temperatures required to pour steel for 1 hour to 1 hour and 55 minutes and making 175 to 270 stops made it impossible to save the furnace at the end of the heat with the gas control. In the next run the



IMPROVEMENTS IN OPEN-HEARTH FURNACE DESIGN.

Fig. 1 is a plan view of the port designed especially for liquid fuel; B is the water-cooled fuel pipe crossing uptake A and terminating above and not extending entirely across A_1. Fig. 2 is a longitudinal section of Fig. 1. This view shows uptake A and A_1 with arch over A_1. Fig. 3 is the same as Fig. 2 except that the burner is not water-cooled. The fuel pipe instead crosses uptake A through a hollow pier E, which protects it from excessive heat. Figs. 4 and 6 are longitudinal sections of the open port type adapted for natural gas, &c. In Fig. 4 the passages for putting air underneath the gas are parallel with the bottom of the port. This is constructed when a bridge wall is used. The passages A_1 are inclined, due to the use of the level port instead of the bridge wall type. Fig. 5 is a plan view of Fig. 6 showing the passages A_1 as they terminate in the port floor. Fig. 7 is a plan of the producer gas type; G is the gas uptake; A and A the air uptakes for the overhead layer of air and A_1 is the air uptake for the lower layer of air. Fig. 8 is a longitudinal section of Fig. 7. This shows uptake A_1, supplying the lower layer of air terminating in the gas port. Fig. 9 is a longitudinal section of the construction used in the gas port arches of Fig. 1, 2, 3, 7, and 8. This view shows the brick in the ring inclined away from the bath at a substantial angle.

cross-section of the port was reduced $3\frac{1}{2}$ sq. ft. This gave a very low and safe flame which was smoky on the bottom. The average time of the heats, however, was 8 hours and 15 minutes. When this smoky flame was noticed it occurred to the author that the control of the flame might not be sacrificed in order to get good combustion if some construction could be devised suitable to the open-port type of the furnace.

The following experiment was made, which clearly brought to light the solution of this problem: A piece of pipe 4in. diam. and about 5ft. long was placed on the port. One end was out in the air uptake, the other well down on the port under the gas layer. It was thought that the natural draught of the furnace would pull some air through the pipe and supply the under part of the gas layer with oxygen. The result surpassed our expectations. The smoky flame was turned to pure white, such as we had never seen before. But, of course, in two reversals the pipe was melted.

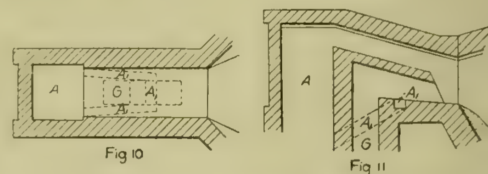
Our other furnace was being rebuilt, and the necessary construction was installed to utilise this fundamental principle. On the previous run of this furnace oil was used for fuel. The furnace was built on the producer gas type of port. Water-cooled burners were installed in the gas port. The ends of the burners were well down in the gas port. The combustion not being good they were gradually pulled back. The combustion improved, but no sharp change took place until the burners were drawn back across the uptake. Then the flame immediately changed to one of intense heat; the bottom of the port melted and the rings of the arch began to drop down. The heats made this way were two hours shorter than when the burner rested on the port.

From the above lessons and search after an efficient furnace the following principle was evolved and patented: A fuel to be burned efficiently and safely must be introduced into the furnace between an upper and a lower layer of preheated air, the upper layer being far larger in volume than the lower layer. To utilise the principle, plans were made for natural, producer, and coke-oven gas, oil and tar. Let us take the open-port type, Figs. 4, 5, and 6. This type with the above principle utilised can take oil, natural gas, and coke-oven gas introduced through pipes B. The preheated air comes up uptake A and over the fuel entering at B B. At the same time, part of the air coming up A is by-passed through the passages A_1 and forms a layer of air underneath the gas. This was the construction used in the furnace we rebuilt.

The flame of the furnace is white, and the average time per heat is 4 hours, $2\frac{1}{2}$ hours faster than formerly. Heats have been made in 3 hours and 20 minutes with good stock and fast charging. These heats are all cold charges of 15 tons. The speed of these heats is due to two factors: (1) the excellent combustion of the fuel, and (2) the almost perfect control of the flame which sweeps from one port to the other clear of the roof and down on the bath. The heats contain 30 to 34 per cent. pig iron, and melt at about 0·40 per cent. carbon, with a manganese content of 25 to 30 points, showing that comparatively small oxidation takes place.

The design can, as previously stated, be used with fuels other than natural gas, as the complete combustion possible does not make it necessary to atomise liquid fuel. This will appeal to some operators, because the forced draught of oil and tar is sometimes attended with evil effects to the end walls and checkers. However, for those who wish to use liquid fuel atomised, designs based on the principle enunciated are shown. The fuel pipe in each case is introduced through a water-cooled pipe, or a hollow pier needing no water-cooled tuyere. The pipe passes through uptake A and terminates above, and not extending entirely across uptake A_1 so that the fuel in this case is introduced beneath a layer of preheated air coming from A and above a layer of preheated from uptake A_1. There is an arch over uptake A_1, which is helpful, as a more intimate mixture of air and fuel is obtained. The flame in this case is discharged immediately into the melting chamber, and the heat is taken up by the bath. No damage is done to the furnace port, and a separate protecting layer of air between the roof and flame is provided.

The arch over the uptake A_1 and the arch of the gas port in the producer gas type are so constructed that bricks of each ring are inclined away from the bath at a substantial angle. This simple construction will lengthen the life of the ports



DESIGN FOR OPEN-HEARTH FURNACE USING PRODUCER GAS.

greatly, for gas port arches do not actually burn back; instead the rings of brick usually fall down. This is caused by expansion of the brick with a displacement of the centre of gravity toward the bath. The producer gas furnace, as has been stated, should embody the construction described in the arch of the gas port. This construction coupled with the principle of introducing the gas into the furnace between an upper layer of air coming from uptakes A A and a lower layer of air coming from uptake A_1. Uptake A_1 is located between A and A and terminates in the gas port. This construction will change the producer gas furnace from a comparatively slow process to a fast one. The smoky roll will disappear as it did in the natural gas furnace, and the layer of gas next to the bath will develop a high temperature where it is needed. If a producer gas furnace were built on the design of Figs. 10 and 11, the author believes that the control of gas would be secured together with quick and perfect control.

DESIGN, CONSTRUCTION, AND INSPECTION OF LOCOMOTIVE BOILERS.*

(*Concluded from page 29*).

Tubes.—It is the consensus of opinion that 2in. tubes are preferred, until the length of tube exceeds 16ft., at which time $2\frac{1}{4}$in. tubes are preferred. Taking into consideration that a 2in. tube will give a greater amount of tube-heating surface, and the cost of maintenance is less, and less damage is done to the tube sheets in working over flues, your committee suggests that further consideration be given to the use of 2in. tubes in lengths greater than 16ft.

Thickness of Front Tube Sheet.—One-half inch and $\frac{5}{8}$in. plate is being used in the majority of cases. One road uses $\frac{9}{16}$in. and another uses $\frac{3}{4}$in.

Thickness of Back Tube Sheet.—One-half tube sheets are being used by 16 roads. Two use $\frac{9}{16}$in. and one uses $\frac{5}{8}$in. All but three report having more or less trouble with flue sheets on account of frequent work on the flues, causing the flue sheets to crack across the top of the flange of the sheet.

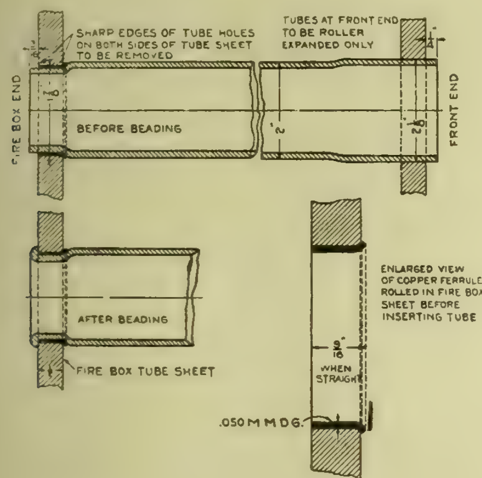


FIG. 16.

Width of Bridges.—Width of bridge in the front tube sheet varies from $\frac{1}{2}$in. to $\frac{15}{16}$in. Three-fourths inch is used by a majority of the roads. The width of bridge in the back tube sheet varies from $\frac{11}{16}$in. to $\frac{15}{16}$in. Three-fourths inch is used in a majority of cases.

Flue Setting.—Two roads have tried out soft iron ferrules with very little success. One road has had a limited experience trying to set flues in the back flue sheet without any coppers, but found that it did not work satisfactorily, and is now experimenting with a combined copper and iron ferrule, but has not had these under test long enough to make any report. One uses soft iron shims on the front flues to avoid excessive expanding.

Setting of Flues in the Front Tube Sheet.—The concensus of opinion of the roads reporting is that tubes should be rolled in the front tube sheet without ferrules, and 10 per cent. of the flues, equally distributed, should be beaded with a beading tool.

Tube Setting in Back Sheet.—Figs. 16, 17, and 18 show the practice followed out by some of the roads in setting the tubes, which are giving good results. Fig. 18 shows the application, maintenance, and removal of flues in locomotive boilers as used by three roads. Tube setting of this kind gives a large bridge, good circulation of water at the back tube sheet, and at the same time the inside of the flue is reduced at the end so that any cinders which will pass through the swedged end will not clog the flues. The instructions in connection with this plate are as follows:—

Preparing Flue Sheets.—Holes in new firebox flue sheet shall be $1\frac{7}{8}$in. diam. Holes in new smokebox flue sheet shall be $2\frac{1}{32}$in. diam. Holes in old flue sheet more than $\frac{1}{32}$in. out of round must be reamed, reamer No. 1. Inside and outside edges of flue holes in both sheets must be slightly rounded to remove sharp edges.

Flue-sheet Holes (No. 1).—Care should be taken that holes in flue sheet are true, smooth, and free from burrs and sharp edges. It is desirable that the flue hole have a fillet, especially on the water side, of about $\frac{1}{32}$in. radius. A sharp edge around the hole often cuts the ferrule in two, even cutting into the flue. The diameter of the flue hole should be the same as outside diameter of flue plus $\frac{1}{32}$in.

Copper Ferrule (No. 2).—For new work this should not be far different from No. 16 B.W.G. In old flue sheets when the flue holes are large it is desirable to use enough heavier ferrules to bring the internal diameter of ferrule when expanded into flue sheet to $\frac{1}{8}$in. less than flue diameter. The ferrule should be set into flue hole flush with fireside and expanded into place with Prosser expander, No. 3.

Swaging Flue (No. 4).—Great care should be taken to give the swage the right length, and to have it terminate in as abrupt a shoulder as possible. The flue, after it is swaged, should be annealed and the scale removed from the portion entering the sheet. Grinding this scale off by machine is desirable, but in the absence of a grinder the removal of the scale with a file will answer. The flue when driven into the sheet (Fig. 5) should extend $\frac{3}{16}$in. through the sheet on the fire side.

Rolling (No. 6).—The front end of the flues having been shimmed, when necessary, both the back and front ends are rolled with dudgeon or other suitable roller—with proper appliances they may be safely and economically rolled by air; the rolling of the back ends must be done by an experienced boilermaker, and the motor must not be larger than a Thor No. 22 or its equivalent.

Beading (No. 7).—This may now be done with a beading tool in an air hammer. Do as little hammering with the beading tool as possible, and do not work bead to a feather edge, but leave as much metal as possible for future caulking.

Expanding (No. 8).—Particular stress should be placed upon this, the most important step in the flue-setting process. Care should be taken that the flue shoulder when heavily expanded bears snugly and firmly against the flue sheet. Hammer not to exceed 4lbs. after prossering the front ends, then bead a sufficient number for safety, which finishes the flue setting.

Back ends of flues or safe ends when used in back flue sheet must be cut off square in pipe machine and burr removed by reamer.

Wheel-flue cutters must not be used, on account of leaving a heavy burr which splits when beading over.

Applying Copper Ferrules.—Copper ferrules $1\frac{3}{4}$in. inside diameter, $\frac{1}{2}$in. long, ·095in. in thickness, shall be used in fire-box flue sheet only. Ferrules shall be secured in place with straight expander, No. 2, taking care that shoulder of expander is tight against flue sheet, which shall bring edge of ferrule $\frac{1}{32}$in. from fire side of sheet.

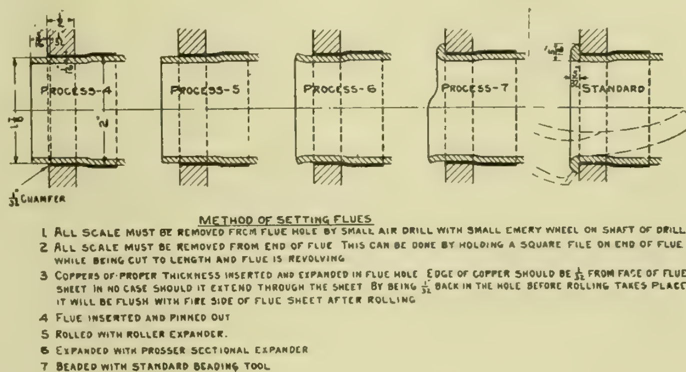


FIG. 17.

Preparing Flues.—Flue safe ends should be 5in. in length, except that new iron flues shall have safe ends 4in. long, and when these flues are first removed the 4in. ends will be cut off completely and 6in. ends applied, after which 5in. ends should be used. Flues shall be swaged as per No. 4, to $1\frac{11}{16}$in. outside diameter by 3in. long, including taper at firebox end, for new work; for old work, just enough to enter the copper ferrule. All scale must be removed from swaged ends

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* Abstract of a committee report presented at the annual convention of the American Railway Master Mechanics' Association.

of flues before application. Smokebox end of flues shall not be more than $\frac{1}{32}$in. less in diameter than holes in the smokebox flue sheet. If necessary, liners may be used.

Fastening of Flue in Flue Sheet.—Flues shall be placed in back flue sheet with a bar, No. 5 (Fig. 20), and project $\frac{1}{4}$in. through the sheet. Gauge, No. 6, shall be used in checking location of flues. Flues shall then be fastened at firebox end with straight sectional expander, No. 7. While flue is being fastened it may be held in place at front end, using bar, No. 5. Straight sectional expander shall be checked with master gauge, No. 8. Before using sectional expander, and in order to obtain exactly the proper length

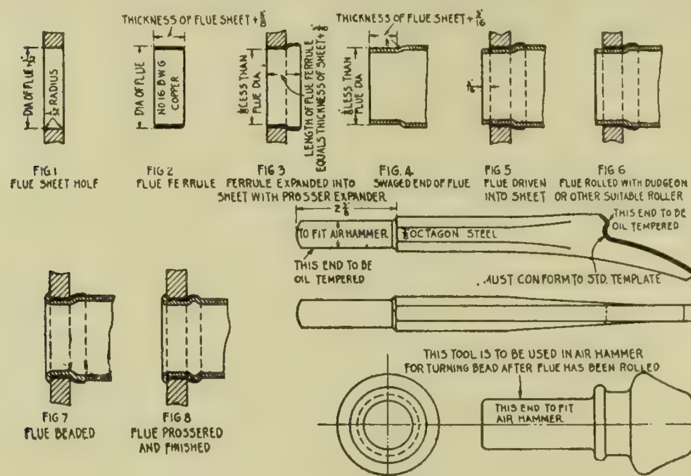


FIG. 18.

of flue for beading, flues may be rolled lightly to fasten them in sheet with roller expander, No. 15. After all flues are fastened they shall be flared at firebox end, using flaring tool, No. 9, and long stroke riveting hammer.

Expanding Flues.—Flues at firebox end shall be expanded with sectional expander, No. 10 (Fig. 20), and long stroke riveting hammer. Roller expander must not be used. Pin shall be driven into expander until flue is solid against flue sheet. This must be done three times, expander to be slightly turned before each operation. The expanding shall be performed as follows: First, two vertical rows, from centre to top of sheet. Second, same rows from centre to bottom. Third, the two horizontal centre rows from centre to right. Fourth, same rows from centre to left. Fifth, all remaining flues. All flues must be carefully inspected after expanding to assure that recess in each flue is the full depth of recess in expander, and even all round the flue. Sectional expander, No. 10, to be checked with master gauge, No. 11.

Beading Flues.—Flues in firebox flue sheet shall be beaded with standard beading tool, No. 12 (Fig. 20), and short stroke riveting hammer. Care must be taken so that nothing enters between head and flue sheet. Beading tool must conform accurately to master gauge, No. 13, at all times. Smokebox end of flues shall be tightened with flaring tool, No. 14, before rolling takes place. All flues in smokebox end shall be rolled with roller expander, No. 15.

Flue Maintenance.—The firebox end of flues in service must be expanded at regular intervals with sectional expander, No. 10. This work shall be done when boiler is empty and all flues thoroughly cleaned out. Flue leaks in the firebox must be stopped with the sectional expander, and not with roller expander nor beading tool. If beads are slightly away from flue sheet, standard beading tool shall be used to bring beads tight to sheet.

Sectional expanders and beading tools must be kept standard by frequently comparing with standard gauges. Any beading tool not conforming to gauge must be sent to principal shop for repairs; these tools must not be repaired at any other shop. All shops and engine-houses must be equipped with standard gauges. All gauges will be made where master gauges are kept. To remove flues, use flue cutter, No. 16, for the front end, cutting off flues as close to the front flue sheet as possible. Back ends should be split as little as possible, so that it will not be necessary to use safe ends longer than 5in.

Setting of Superheater Tubes.—Front tube sheet. Only eight roads have had any experience with setting large superheater tubes. The practice followed out mostly is that the tube is rolled and beaded as shown in Fig. 19, and this type of setting is suggested by your committee for further consideration. Back tube sheet. Eight roads advise that they use copper ferrules; one omitted copper ferrules and is having good success with this method. The concensus of opinion of the roads reporting is that the type of setting shown on Fig. 19 is preferred, and your committee suggests this setting,

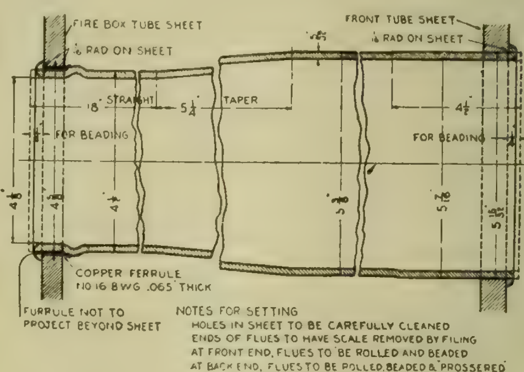


FIG. 19.

except that the copper ferrules should be No. 13, ·095in. thick, instead of No. 16, ·065in. thick.

Circulation of Water.—The committee took up the question with the members whether any of them employed any special feature of design to facilitate circulation of water. It was found no road has any special design for this purpose. Four advise that they use baffle plates in the boiler shells located ahead and rear of the dome; this is to prevent, as much as possible, the water from surging when making quick stops. The committee has no recommendation to make in regard to the use of baffle plates.

Seventeen roads deliver feed water to boiler in the first

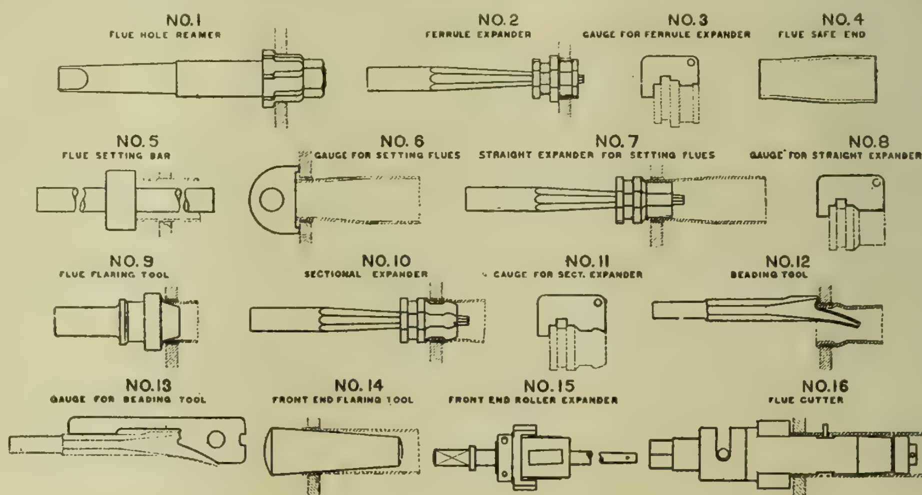


FIG. 20.

course on the horizontal centre line. The distance from the front flue sheet varies; the minimum distance is 22in. and the maximum 6ft. On five roads they deliver feed water to the boiler through the top as well as from the side. One of these advises that they have never been able to find any particular improvement with the top check as compared with the side check. Two prefer the water to be fed into the boiler from the top. Boilers having the checks on top of the boiler have a pan-shape deflector under the check valve which catches the water and prevents any direct stream of water falling on the top of flues. On one road they deliver the feed water in the first course on the horizontal centre line and use a deflector plate placed a short distance away from

the boiler course, this being to direct the water to the bottom without striking the tubes. Four have an attachment on the inside of the injector check to deliver water upwards away from the tubes. One, in addition to circulating water from the horizontal line of the boiler, has some locomotives with the delivery pipe passing through the back head, extending from 3ft. to 6ft. from the front tube sheet, and the end of the pipe set to deliver water towards the side of the shell; the end of the pipe is submerged. The committee has no recommendation to make in regard to any particular location where the water is to be delivered to the boiler, as any of the above arrangements seem to give entire satisfaction.

Location of Blow-off Cocks.—There is no uniform practice in regard to the location of blow-off cocks. On two roads they use four or more blow-off cocks, which are located one in the throat sheet, one or more in the side water legs, depending upon the size of the boiler, one in the belly of the boiler near the throat sheet, and in some cases additional blow-off cocks in the belly of the boiler at the centre. One of these advises it has been found by using a sufficient number of blow-off cocks and insisting upon their use at regular intervals, the amount of boiler washing has been cut down considerably, as well as giving greater life to the flues. Another road has been experimenting with the blow-off system, by which one blow-off cock in the throat sheet draws mud from along the mud ring and the barrel of the boiler by means of slotted pipes, and this has worked out satisfactorily in service. Some favour locating the blow-off cock right above the mud ring, and another locates them about 1ft. up from the mud ring. The committee has no recommendation to make in regard to the number or where the blow-off cocks should be located. The number and location of blow-off cocks depends on the quality of water used.

Filling of Boilers—On one road they have had a number of side sheets cracked by filling through blow-off cocks located in the water legs. It was not stated whether they used cold or warm water. They are now filling through the blow-off cocks located in the barrel of the boiler. Another advises that they have had considerable experience with sheets cracking from the filling through blow-off cocks with cold water. They now fill boilers through injectors when using cold water. It seems to be the concensus of opinion that it is most advisable to fill the boilers from the blow-off cocks in the water leg, providing warm water is used. If cold water is used it should be filled through the valve on top of the boiler or through the injectors, and the committee recommends that this practice be followed out.

THERMIT WELDING.*

BY G. E. PELLISSIER.

THE compound to which the trade name thermit has been given consists of finely powdered aluminium and oxide of iron combined in such proportions and in such a manner as to react when ignited in accordance with the formula, $Fe_2O_3 + 2AL = AL_2O_3 + 2Fe$. This compound has the peculiar property that when ignited in one spot combustion proceeds throughout the entire mass without any supply of external heat, the aluminium reducing the oxide of iron practically to pure metallic iron and combining with the oxygen to form aluminium oxide or corundum. As the reaction is exothermic, an intense heat is generated, the temperature of the molten mass being estimated at about 5,400° Fah. It is also of interest to note that the compound is not combustible in the ordinary sense of the word, as it can be placed upon molten iron without igniting.

In practice the reaction of the mass is started by a special ignition powder which creates an intense temperature at one spot, whence the reaction proceeds of itself without any further supply of heat, requiring less than one minute for completion, regardless of the amount of the compound brought into reaction. As before stated, the product of the reaction is aluminium oxide and metallic iron, the proportion being approximately 50 per cent. of each by weight, but as aluminium will act similarly on the oxides of nearly all of the metals used in making steel, it is necessary only to mix these oxides with the iron oxides in correct proportions in order to obtain practically any steel that is desired.

In applying this reaction to the problem of welding, two quite distinct methods are followed, one of which utilises the heat of the reaction to bring the pieces to be united to a welding temperature, whence they are forced together by suitable clamps and butt-welded in a manner similar to forge-welding. In the other, the ends of the pieces to be united are fused or melted together by the molten metal from the reaction, which amalgamates with them into a molten mass, which is retained by a suitable mould and allowed to cool, thus uniting the parts into one homogeneous mass.

The first method, which is commonly designated as butt-welding, is applied chiefly to welding pipes, tubes and small rods. In making a weld by this method the ends of the pipe to be united are filled or machined to fit closely together, then fastened together with suitable clamps, and surrounded with a cast-iron mould designed to hold just enough of the molten mass to bring the parts to be united to a welding heat. The necessary amount of thermit is then ignited in a small flat-bottom crucible, and as soon as the reaction is over the contents of the crucible are poured into the mould. The aluminium oxide having risen to the top of the crucible, on account of its low specific gravity, flows into the moulds first, and coming in contact with the cold iron adheres to it, forming a thin refractory coating which prevents the molten steel, which flows in later, from adhering either to the mould or the parts to be welded. As soon as the molten mass has been in the mould long enough to allow the heat to penetrate the parts to be welded, a length of time determined by experiment, the pieces are forced together by the clamps, which completes the weld. On account of the fact that pieces thus welded are heated out of contact with the air, no oxidation can take place and consequently no flux is necessary, care being taken simply to see that the parts to be united are clean and bright. Rods up to 2in. diam. and all sizes of pipes from 1in. to 6in. diam., standard, extra heavy, and double extra heavy have been welded by this method.

The chief application of this process is in welding ammonia, compressed air, high-pressure steam and hydraulic lines, where the work has to be done in place. As the outfit required for welding 4in. pipes weighs less than 100lbs. and can be manipulated in a trench wide enough for a man to stand in, lines can be welded which would otherwise have to be provided with mechanical joints.

As an illustration of the efficiency of welds made in this manner, it may be noted that a hydraulic pipe line, 4in. extra heavy, welded for the New York Central Railroad at Albany, was subjected to a test pressure of 3,000lbs. per square inch maintained for 24 hours, and has been operating for two years under a working pressure of 1,500lbs. per square inch with entire satisfaction. Physical tests on welded samples before the contract was awarded showed the strength of the welded section to average from 80 to 90 per cent. of the strength of the pipe in tension and cross bending.

In welding by the second method, the so-called intermediate welding, the parts to be united are not brought close together nor fitted in any way, but instead a space varying with the section to be united from ½in. to 2in. in width is provided to allow a free flow of the molten thermit metal between the ends. After the parts have been thoroughly cleaned of grease, dust, &c., they are surrounded with a refractory mould very similar to that used in making steel castings. This mould is provided with a suitable pouring gate and riser, and in addition to this a gate or opening at the lowest part of the mould used for preheating.

If the parts to be welded are of a uniform section these moulds are made from wooden patterns similar to standard foundry practice; but where the parts to be united are of an irregular section which would involve difficult and expensive pattern work, such as in repair work, the so-called wax method is used. In this method the space between the parts to be united is filled with wax and a reinforcing collar of any desired dimensions is formed of the same material. As soon as the wax is hard the parts are surrounded with a mould box

* Paper read before the American Society of Mechanical Engineers.

and the mould rammed in place, wooden patterns being used for gates and risers. Heat is then applied through the preheating gate at the lowest part of the mould, which melts the wax, allowing it to flow out and leaving a cavity in the mould of the exact dimensions desired. The preheating is then continued until the mould is thoroughly dried and the ends of the pieces to be welded are brought to a bright red heat. While the preheating is going on, a so-called automatic crucible, having a small opening in the bottom with arrangements for pouring and tapping, is placed over the heating gate of the mould, into which are poured the thermit and additions.

The amount of thermit necessary to fill the mould is obtained by weighing the wax used and multiplying the weight by 32. This is obtained by multiplying the weight of wax by the ratio of specific gravity of wax to that of iron, approximately, then by 2, as thermit is half iron, and again by 2 to provide for metal in the riser. To the thermit is added the proper amount of carbon steel punchings, nickel chromium, manganese, &c., to give the resulting steel approximately the same analysis as the pieces to be welded. These alloys can be added in the form of shot or as manganese thermit, chromium thermit, &c.

In making welds in this manner the usual precautions have to be taken to provide for the contraction of the metal when cooling whenever possible. Welds can, of course, be made where it is impossible to provide for such contraction, but the welds will then be subjected to the internal stresses due to cooling. This method of welding has its chief application in welding rails for street railway companies and in repairing all kinds of machinery where the sections to be welded are large, and where the work of necessity has to be done rapidly or in place. Among such repairs might be mentioned the welding of engine frames, crank shafts, stern and rudder posts of vessels, flywheels, and large castings of every description.

A brief description of a few representative repairs will serve to illustrate what may be accomplished by this method of welding.

In getting away from her pier in the Lachine Canal, the "Corrunna," a vessel of 1,296 tons register, 35ft. beam and 21ft. depth, was caught by the current and swung against the walls of the canal, the skeg being broken off close to the keel and the rudder post 10in. above the top of the rudder. As there were no facilities in Montreal for making a repair of this nature, it would have been necessary to tow the vessel to Cleveland. Both of these welds were made in five working days without removing the stern frame.

The steamship "Duluth," which is 404ft. long, 50ft. beam, and 6,400 tons registered, had its rudder frame broken 10in. aft of the rudder post, the section to be welded being 2½in. by 9½in. The work of welding was carried on without docking, rafts made fast to the vessel, and required only two days for completion.

A flywheel, weighing 48 tons, was wrecked at Sylva, N.C., when the car upon which it was being transported overturned. The wheel, which was 24ft. diam., 74in. face, and weighed 48 tons, was cast in four pieces. The piece wrecked was broken through the rim, the section of the fracture being about 3½in. by 37in., with ribs at the edges 3½in. by 6in., and one of the spokes was broken near the hub and near the rim, sections at fractures being about 8in. by 11in. elliptical. The repair was made in the wilderness where the wreck occurred, the nearest machine shop and source of supplies being 50 miles away. The flywheel has been in continuous service over two years under severe conditions, as the 750 h.p. engine and generator of which it is a part are frequently subjected to a 50 per cent. instantaneous overload.

A steel gear driving a so-called continuous rolling mill at the works of the American Tool and Stamping Company, at Bridgeport, Conn., was broken in two places. The gear is 6ft. diam. with a 22in. face. The time required for making these two repairs complete was 46 hours.

The main driving shaft of the 750 h.p. engine and generator at the Binghamton Railway Light and Power Company, Binghamton, N.Y., was 15ft. long over all and varied in diameter from 10in. to 16in. The crank webs, one of which was broken in two places, are 28in. by 18in. by 6½in. The work of welding was not done in place in this instance but at the shops of the Goldschmidt Thermit Company, as it was impossible to align the shaft properly in the power station. The operation required three days.

TABLE I.—*Bending Tests.*

Description.	Size of Bar, In. Diameter	Span, Ft.	Total Load, Tons	Angle Bent Through	Effects
Solid bar	2	15	10·18	180	Uncracked
Thermit welded bar, bulb turned off	2	15	10·09	46	Broken at weld.
Thermit welded bar, bulb left on	2	15	17·30	125	Bent as far as practicable. Uncracked.

TABLE II.—*Tension Test.*

Riehle Brothers Testing Machine Co., Inc., Philadelphia, April 7th, 1908.

Size, In.	Area, Sq. In.	Elastic Limit, Lb.	Elastic Limit. per Sq. In., Lb.	Ultimate Strain in Lb	Ultimate Strain per Sq. In., Lb.
749	0·441	18670	42330	27930	63330

As regards the efficiency of welds made in this manner, the physical tests and chemical analyses in Tables I. to III. show clearly that the metal of the weld is practically equal in strength to the metal of the parts repaired, except possibly in the case of special steel alloys. When it is considered, however, that the section at the fracture can be increased to any desired dimension when the repair is made, it will be readily seen that the repaired section can be made stronger than it was originally. The section tested in tension was taken from a weld on a section 6in. by 8in. and was turned from the thermit metal and not subjected to annealing or forging.

Table III., giving the chemical analyses of welds made on carbon steel and carbon steel containing nickel, illustrates how closely the material of the weld approaches that of the metal welded.

TABLE III.—*Chemical Analyses of Welds.*

	NICKEL STEEL.					CARBON STEEL.			
	C	M	S	P	N	C	M	S	P
Steel ...	0·92	0·76	0·029	0·018	1·06	0·55	0·89	0·068	0·09
Weld ...	0·36	1·21	0·019	0·036	1·11	0·48	0·90	0·032	0·063

The process of welding is invaluable for all kinds of repair work, not only because by welding broken parts the pieces themselves can be made as good as new, thus saving the original cost, but on account of the extreme portability of the outfit and because in nearly all cases the welding can be accomplished on the spot, thus saving a great deal of time and keeping a plant or ship in operation when it would otherwise have to be put out of commission for days, weeks, and sometimes months.

The Institution of Mechanical Engineers' Summer Meeting.—As previously intimated, the summer meeting of this Institution will be held in Belfast, and will begin on Tuesday, July 30th. The following papers have been offered for reading and discussion, and will be presented as time permits: "New Graving Dock, Belfast: Mechanical Plant and General Appliances," by Mr. W. Redfern Kelly, of Belfast; "Rolling Stock in use on the principal Irish Narrow-gauge Railways," by Mr. R. M. Livesey, of Stranorlar; "The Evolution of the Flax Spinning Spindle," by Mr. John Horner, of Belfast; "Wire Ropes for Lifting Appliances, and the Conditions that Affect their Durability," by Mr. Daniel Adamson, of Hyde; "Reciprocating Straight-blade Sawing Machine," by Mr. Charles Wicksteed, of Kettering; "Commercial Utilisation of Peat for Power Purposes," by Mr. H. V. Pegg, of Belfast. During the course of the meeting arrangements have been made for visits to engineering works and other places of interest in the neighbourhood.

DUST EXPLOSIONS IN FACTORIES.

THE occurrence of several disastrous and fatal explosions from the ignition of dust in factories during the year 1911 led to the matter being specially investigated by W. S. Smith, H.M. Inspector for Dangerous Trades, and forms the subject of some interesting remarks by him in the annual report of the Chief Inspector of Factories.

At Manchester, on March 21st, 1911, an explosion occurred in two six-storied buildings used as a starch and gum factory. The explosion swept through the two buildings and set them on fire, and led to three persons being killed and several others injured. At the coroner's inquest doubt was expressed as to whether starch dust could account for the effects observed, and it was suggested that an explosive mixture of gas and air was the cause. Mr. Smith, however, states that the circumstances pointed rather to ignition of starch dust by a fire in a room of one of the buildings used as a warehouse as a more probable cause. Although starch dust is generally regarded by the trade as non-explosive, flashes of fire have, he says, been observed in one dusty starch factory, and precautions are taken to prevent carrying and striking of matches and the use of naked lights on the premises, while it has been shown experimentally that explosions may be produced by dropping finely-powdered starch down a tube at the bottom of which a naked light is burning. There are no previous records of explosions in this country attributed to starch dust, but it has since been ascertained that a terrible explosion occurred in 1908 in the mixing department of a starch factory at Providence, U.S.A., through which six men were killed and a number of others injured.

At Glasgow, on November 10th, 1911, five persons were killed and eight injured by an explosion at a provender mill. The premises consisted of two adjoining blocks of five-floored buildings, one used as the mill and the other as a warehouse. In this case the front wall of the premises was blown into the street, and the warehouse completely collapsed, as shown in the accompanying photo views. Millstones were at work at the time of the disaster, grinding peas and beans. After careful enquiry, Mr. Smith came to the conclusion that the explosion was due to the ignition of carbonaceous dust, such as finely-divided bean and pea meal, by a naked light. All the circumstances pointed to the millstone floor as the seat of the initial explosion, and to a fall of meal dust from an overhead beam on a naked flame as the cause. Accumulations of meal dust were present in the mill, and probably in the warehouse, in sufficient quantity to be disturbed by an initial explosion. The presence of this disturbed dust in the atmosphere of the rooms was responsible for the transmission of the explosion wave through the entire building and for the damage to the premises. A sample of the meal dust taken from one of the overhead beams was tested for inflammability at the laboratory of the Committee on Explosions in Mines; the dust was blown into a tube across a heated platinum wire coil, the temperature of which was accurately known. It was found that for this apparatus the ignition-temperature of the dust was 1,050° C., and the flame travelled along the whole of the tube as a bright flash, the speed of travel being appreciably faster than in the case of coal-dust samples treated in a similar manner. The average ignition-temperature for samples of coal dust, similarly determined, was 1,060° C.

The disastrous explosion at Messrs. Bibby's oil-cake mill, Liverpool, on November 24th, resulted in 39 deaths and injuries to over 100 persons. The damage to property was chiefly confined to three adjacent blocks of five-floored buildings, where processes in the manufacture of oil cake were carried on, including the grinding of cake, nuts, locust beans, &c. In this case the explosion was traced to ignition of dust in the disintegrator room situated in the basement of the central damaged block. Tests of various samples of similar dust showed that it was exceedingly inflammable, and capable, when present as a cloud in the air, of causing self-propagation of flame with ultimate explosive effects. The ignition-temperatures of five samples by a hot platinum wire varied between 1,040° C. and 1,070° C., and it was shown that the dusts, if formed into a cloud, could be ignited by a naked gas flame, the striking of a match, an electric spark produced by breaking an electromagnet circuit (100 volts), or the melting of an electric fuse wire on a 100-volt circuit. The evidence pointed to ignition of a dust cloud as the cause, and as experiments have shown that about 2ozs. of coal dust per cubic yard of air are necessary for ignition and flame propagation of such dusts, probably a similar proportion is necessary to ignite the carbonaceous dusts of cake mills, provender mills, flour mills, and other works of this kind. Such an abnormal quantity of dust in the atmosphere could have been produced by the breaking of a belt in the room and striking, after fracture, the accumulations of dust on beams, ledges, and plant in the neighbourhood. There was evidence that similar belts had previously broken, forming very thick dust clouds. A large disintegrator driving belt was found after the explosion to be broken, and the breaking of this belt and ignition of a dust cloud so formed, may be regarded as the most probable cause of the explosion, though the exact cause of ignition could not definitely be stated.



FIG. 1.—DUST EXPLOSION AT A GLASGOW PROVENDER MILL. VIEW OF WRECKED PREMISES.

In December a less serious dust explosion occurred in a large dust-collecting house of a cattle-food works at Aberdeen, in which oat husks were being ground. In this case a large window, originally fixed in the dust-house to take the force of any explosion, probably saved the building from being wrecked, and automatic sprinklers prevented the spread of fire from the dust-house to the mill. The millstones were faced with emery and set very close to each other. The explosion was considered to be due to ignition of dust in the dust-house by sparks from a piece of metal between the stones

After the Manchester explosion, instructions were issued to the inspectors to report as to (1) the class of works in which carbonaceous dust is produced in large quantities, (2) the occurrence of dust explosions, and (3) the precautionary measures in use, *e.g.*, the avoidance of exposure to naked lights. The reports received from the staff dealt with a large number of trades in which such dusts are produced in the process of manufacture. In the following table the different classes of works are arranged according to the nature of the dusts liable to be present, and those marked with an asterisk indicate works where explosions have been recorded.

Works containing farinaceous, saccharine, and starchy dusts. (1)	Works containing carbonaceous dusts, *e.g.*, charcoal, coal, coke, graphite, &c. (2)	Works containing dusts of vegetable origin, *e.g.*, cork, wood, &c. (3)	Works containing dusts of animal origin, *e.g.*, bones, hoofs, horn, &c. (4)
*Breweries.	*Briquette works.	*Cork grinding (linoleum).	Bone grinding works.
Cattle food works.	*Cement works.	*Saw mills (sandpapering).	*Refuse hoof and horn grinding works.
Confectionery works.	Charcoal grinding.	Sawdust grinding and wood flour mills.	
Cocoa works.	Coal washing.	Snuff mills.	
*Distilleries.	Coke ovens.	Tea factories (sifting).	
*Flour mills.	Electric carbon works.		
Food mills (corn flour).	Foundry blacking works.		
*Grist mills.	Gas works.		
*Maltings.	Lamp black works.		
Mustard mills.	Mineral and ivory black works.		
*Oak husk grinding.	*Phonograph record works.		
Rice mills.	*Rag carbonising works.		
Saccharine works.			
*Seed crushing.			
Spice mills.			
*Starch and gum works.			

Explosions were generally found to be due to the following causes:—

(1) Falls of accumulated dust from beams, rafters, and ledges upon naked lights.

(2) Falls of accumulated dust upon burning plant or machinery during a fire on the premises.

(3) Introduction of naked lights, *e.g.*, candles, oil lamps, or defective safety lamps inside elevator casings, mills, dust collecting chambers, or other confined spaces.

(4) Production of sparks in a dusty atmosphere, owing to presence of particles of grit, flint, or metal in the mills or other machinery.

The provision of effective exhaust ventilation, increased use of electric lighting, avoidance of use of naked lights, prohibition of smoking and carrying of matches, and frequent cleansing of floors, beams, rafters, and other ledges on which dust could accumulate, appeared to be important factors in preventing explosions in many works and in eliminating the risk of explosions in factories where dust explosions had occurred in the past. Other precautions observed by the inspectors included use of explosion doors on elevator casings and dust collecting plant, installation of automatic sprinklers, and provision of efficient governors to prevent racing of machinery. Special attention has been given to the various classes of works in which carbonaceous dust is produced; occupiers have been warned of the risk of explosions in dusty confined spaces or from accumulations of dust, and of the need for observance of the above-mentioned precautions, where practicable, especially those dealing with avoidance of naked lights and frequent cleansing of floors, beams, and ledges.

Dealing with the various classes of works mentioned in the table, the following observations are made:—

Breweries.—Dust is generated in the cleaning of grain and at the malt mills, elevators, and grain hoppers. The dust in grain dressing is a mixture of mineral and carbonaceous matter, and is probably not so inflammable as the dust at the malt mills and elevators which is of a saccharine nature. Explosions are reported from Edinburgh and other places. These have occurred at the malt mills, at the malt mill elevators, and at the hoppers over mash tuns, due to use of naked lights or to production of sparks at the steel rollers of the malt mills owing to presence of flinty particles in the malt. Electric lights and portable electric lamps are now generally in use in the larger breweries. Other precautions which have been noted to reduce the risk of explosion include the provision of flap doors to malt mills and the covering of openings at regular intervals in the malt elevators with brown paper.

Confectionery Works. Much dust is often found in works where jellies, fondants, and gums are manufactured. Powdered starch is used to form the moulds for the jelly or fondant preparation. The trays of moulds are dried in hot stoves and the dry sweets are separated from the starch by sieving and brushing. Even where these operations are carried on in enclosed machines, much dust is usually present. In some works the use of electric lights or enclosure of open gas jets in lanterns is fairly general, and naked lights are forbidden.

Distilleries. The dust is of a starchy nature derived from sago and maize meal. Two explosions have been noted, at Hammersmith, one about 20 years ago and the other during 1911. Both explosions occurred at sago meal elevators, due to falls of accumulations of dust on naked lights; these have been replaced by electric lamps.

Flour Mills. Serious explosions have been recorded in the past at Cardiff, Dundee, Edinburgh, London, and Liverpool; the latest occurred at a Liverpool flour mill about seven years ago. The causes of the explosions have been attributed to absence of dust-collecting plant or to fires, or use of naked lights in or near the dust-collecting chamber or "stive room." Such chambers are now seldom found except in the older mills; they have been largely replaced by cyclone collectors or by bag filters of various types. Where "stive rooms" exist these are generally used to collect the flour dust from the roller mills and elevators, whilst the dust from offal grinding is collected separately in bags or blown into the open air. Some collecting chambers have hinged balanced windows to act as explosion valves in case of explosion within the chamber. Absence of dust due to introduction of roller machinery with efficient dust-extraction plant, the general use of electric lighting, and the avoidance of naked lights, appear to have been the principal factors in preventing explosions in recent years. Reports show that even in the old mills naked lights are avoided as much as possible, care is taken to keep gas jets several feet away from sources of dust, and cleaning of dust-collecting chambers is done during daylight. Fire insurance premiums are reduced where locked portable lamps of an efficient type are in use, or where the mills are lighted electrically or provided with fire-extinguishing appliances. Other precautions include the frequent sweeping of floors, beams, and all parts where dust is liable to accumulate.

Grist Mills.—In addition to the recent explosion at a Glasgow provender mill, a serious explosion occurred about 11 years ago at a barley mill in the Edinburgh district: a grindstone burst, the flying fragments dislodged a quantity of dust from the rafters, the dust cloud was ignited by an exposed gas jet, and the side of the mill was blown out. In some quarters it has been stated that the dust often consists of carbonaceous and siliceous particles, and the risk of explosion is reduced in consequence. Experiments with similar dust from granaries have shown, however, that flame propagation is possible notwithstanding the presence of a considerable amount of earthy matter in the dust. Dust extracting and collecting plants are usually absent, and naked lights are often used. These are matters which should receive attention, and further precautions should include the careful examination of millstones and the prevention of racing of grinding machinery.

Maltings.—Recorded explosions are of a similar nature to those in breweries, and these are fairly common at the malt mills. Several have been reported from Burton-on-Trent during the past five years. The introduction of a lighted candle into a mill as soon as grinding had ceased was responsible for one explosion; others were attributed to production of sparks at the steel rollers owing to presence of particles of flint in the

mills, or to use of naked lights. Electric incandescent lighting is often installed and portable electric lamps are now generally used during examination of elevators and malt mills.

Oat Husk Grinding.—This process is carried on chiefly in the North of Scotland and Ireland, in the manufacture of cattle food, and two explosions in dust collecting chambers and several fires have been recorded. Sprinkler installations have proved effectual on several occasions. In a recent explosion the provision of a large window in the dust house probably prevented destruction of the building. In other cases, dust houses have been abolished and replaced by cyclone collectors fitted with explosion flap valves.

Rice Mills.—Both in mode of working and in machinery these works resemble the old-fashioned corn grinding mills. Considerable dust is given off at the millstones. In some works, electric lamps or enclosed gas lights are used. It has been urged by some occupiers that dust-collecting plant would increase the risk of explosion in the ducts and other confined spaces, but efficient localised exhaust has apparently been an important factor in preventing risk of local explosion in flour mills, where the dust is somewhat similar.

Seed-crushing Mills.—Dust escapes in considerable quantity in some of the processes, and it is reported that localised exhaust ventilation would be difficult in some cases without reconstruction of the machinery or improved plant. The dust is oily, and very inflammable. Fires, due to spontaneous combustion, might be expected from its nature, but few occur. In addition to the recent disastrous explosion at Liverpool, a serious explosion also occurred at Liverpool in 1908. The dust in the seed-drying tower either became overheated or ignited spontaneously, and caused a slight explosion, which dislodged a quantity of dust from the rafters of an adjoining room, in which a more serious explosion immediately occurred. Two men were killed, and four other persons were injured. Increased attention to efficient removal and collection of dust is necessary, including, in addition to exhaust ventilation, frequent sweeping of floors and prevention of accumulation of dust on beams, rafters, and ledges. Extended use of electric lighting has probably reduced the liability to explosions, and naked gas lights had already in many instances been discarded. In spice mills, edge runners and stones are used as grinding machinery, and considerable dust escapes in the processes. Localised exhaust ventilation is usually lacking, and is often impracticable in many mills unless the plant is entirely reconstructed. At one large works, absence of explosions during the past 40 years is chiefly attributed to great care in cleanliness and constant sweeping of floors, rafters, and other places where dust may accumulate: unless this is done there is grave risk of explosion.

Starch and Gum Works.—The recent case in Manchester is the only recorded instance of a serious explosion at a starch factory in the United Kingdom. It is reported that many occupiers and managers of works are sceptical as to danger from starch dust, though one large firm, whilst considering their starch (rice starch) non-explosive, recognise that it is inflammable, and prohibit the use of naked lights. In some districts, great care is exercised in this direction; the factories are lighted by incandescent electric lamps, smoking is prohibited, and matches are not allowed inside the works. In other parts of the country, naked gas jets are used daily, though the atmosphere of the rooms is admittedly dusty.

Briquette Works.—Explosions of coal dust are possible at the screens, pug mills, and coal bunkers. An explosion occurred several years ago at a pug mill in a Cardiff works. Slight explosions, causing burning accidents, frequently occur in the Swansea district, and occasionally happen in underground shafting tunnels, where quantities of fine dust accumulate in confined spaces. An explosion, causing injury to a person carrying an oil lamp, and due to a fall of an accumulation of dust on the naked light, is reported from Scotland. Naked lights are generally avoided, and safety lamps are used in some works. Exhaust ventilation, frequent sweeping, and electric lighting are the precautions generally observed.

Cement Works.—In the modern manufacture of Portland cement, the fuel used in the rotary kilns consists of coal dust which is blown under pressure into the combustion chamber of the kiln. The raw coal, freed from moisture in a rotary drier, is ground to an exceedingly fine powder in tube or pendulum mills. Little dust escapes from the most modern coal-grinding plants, but in older works there is often excessive dust. A few explosions, due to use of naked lights, occurred in the early days of the rotary kiln. One happened in a coal dust hopper which was undergoing repair; two men who were using an oil lamp were injured. The danger of explosion from coal dust is now recognised at all cement works, and at many of the coal grinding mills warning notices are posted prohibiting smoking or the use of naked lights. Electric incandescent lamps are generally used. Dust-collecting plants, including bag filters, are installed in some mills, whilst in others the whole of plant (mills, elevators, and conveyers) is connected directly to the dust-supply pipes feeding the rotary kilns. Both systems are equally effective for preventing escape of coal dust.



FIG. 2.—DUST EXPLOSION AT A GLASGOW PROVENDER MILL. VIEW OF WRECKED PREMISES.

Gas Works.—Attention has been directed to the dusty condition of elevator chambers in some gasworks. No explosions have been noted, though naked gas jets are often used to light the chambers. Probably the dust in the atmosphere is insufficient in quantity or too damp to propagate a flame and explode. The danger of use of naked lights in such places has, however, been strongly urged.

Lampblack Works.—Lampblack is manufactured by the imperfect combustion of petroleum oils. Occupiers of works are sceptical as to danger, as naked gas flames appear to have been used for years without any record of explosion. They have, however, been urged to avoid naked lights.

Mineral and Ivory Black Works.—The materials are manufactured from animal, mineral, and wood charcoal. There is no record of explosions, though naked lights are used, and a considerable amount of fine dust is generated, notwithstanding the fact that the mills are generally equipped with exhaust ventilating plant. Occupiers have been warned as to the danger of naked lights.

Phonograph Record Works.—The records are composed of graphite and resin, which are finely ground together in mills. One explosion, with injury to two persons, has been recorded. This occurred at the outlet of a mill, and was probably due to presence of grit between the rolls. Since this explosion, smoking and introduction of matches have been prohibited in the works, which are now lighted electrically.

Rag Carbonising Works.—The cotton fibre present in woollen rags is removed from the wool by exposing these to the action of heat and hydrochloric acid vapour; the cotton is converted into glucose which is afterwards beaten out of the carbonised rags in shaking machines. If metallic substances, such as buttons, are present, sparks are often produced by the beaters of the machines, causing explosions of dust. The explosions usually happen when the rags are being fed into the shaker and persons are occasionally burnt. The following precautions are recommended: reducing the density of the dust-laden atmosphere within the shakers by using larger machines, or introducing more efficient fan exhaust, or slower feeding of the machines with smaller quantities of rags; cooling the rags before placing them in the shaker; opening and closing the shaker door from a distance by means of a rope.

Cork Grinding.—A large amount of dust is produced in grinding cork and wood for use in the manufacture of linoleum. An explosion, with injury to one man, occurred at Dundee in 1902, owing to ignition of dust. In order to prevent a fire in a dressing machine from spreading, this man went on the rafters to collect the accumulations of cork dust, and accidentally upset a large pail containing the dust on to the burning machine below. Naked lights and smoking are generally prohibited in these works; the means of illumination consist of incandescent electric lamps or screened oil lamps, though occasionally exposed lights are used in dusty chambers without occurrence of explosions. Probably in such cases the quantity of suspended dust is insufficient to propagate a flame, but the danger from accidental dislodgment of dust must always be present. Settled accumulations of dust are generally avoided, however, and rafters and beams are frequently swept.

Sawmills.—One instance has been recorded of an explosion, with injury to workmen, due to ignition of the fine dust from a sandpapering machine in a sawmill. Localised exhaust ventilation is now general for sandpapering machines, and complete dust extracting plant is often installed for all good working machinery in sawmills. Many works are lighted by electricity. Fires have occurred in the grinding of sawdust, but there is no record of explosions. Enclosed oil lamps or incandescent electric lamps are used in several factories. Naked lights and smoking are prohibited. The general precaution in this trade is to avoid accumulation of dust.

Hoof and Horn Grinding Works.—Three explosions occurred prior to 1906 at a factory in Aberdeen, probably due to sparks in the disintegrators caused by pieces of iron in the refuse hoofs. Much dust existed in the works at that time, but since the installation of an efficient dust-collecting plant, including bag filters, there has been no recurrence of explosion, and the factory is now practically dustless. Extra care is taken in sorting to remove all pieces of iron or steel from the material.

Automatic Coaling Plant.—It is announced that the automatic coaling plant for Delagoa Bay, devised by Mr. G. Provay, is to be adopted. It is expected that it will be in full working operation within 12 months.

THE PROPER TREATMENT OF COMMUTATORS AND BRUSHES.

As most electricians know, a very large part of the attention required by direct-current dynamos and motors must be given to the commutators and brushes. Our contemporary the "Electrical Review and Western Electrician," referring to the proper treatment of these, says that while much of the matter on this subject appearing in technical publications from time to time is decidedly good, some of it is of such a character as to induce the inexperienced operator to resort to an excessive use of foreign substances on commutators and brushes. If the commutator be kept round, and smooth, and clean, and the brushes in proper adjustment, there should be but little trouble from sparking or heating in the operation, at or below the rated load, of a dynamo or motor of any of the usual types—it being assumed, of course, that brushes of the right sort are used. The common practice of applying vaseline or oil to a commutator whenever a spark appears without any attempt to locate the cause of it is as bad as it is common. When these lubricants, or even the best of the commutator compounds, have to be used at all they should be applied in very small quantities usually, and the necessity of frequent applications can be taken as a certain indication that something is wrong with the machine. Our contemporary recalls an experience in which it suddenly became impossible to hold the voltage on a large alternator at anything like its rated value. After nearly an hour of unsuccessful efforts to find the cause of the disorder it was discovered that an attendant had applied to the commutator of the exciter an excessive quantity of a substance which he had been using in smaller quantities on the commutators of other machines in the building. An application or two of a clean cloth saturated with benzine cleaned the commutator and removed the trouble with the alternator voltage. Carbon brushes which have been in use a long time may sometimes be improved by the boiling process often recommended, but paraffin is better for this purpose than any sort of oil. When the time for boiling has been reached, however, better results at a smaller cost may very often be had by purchasing a new set of brushes.

British Foundrymen's Association.—The ninth annual convention of this association will be held at the University College of South Wales, Cardiff, on August 6th, 7th, and 8th. On the Tuesday morning the election of officers will take place, after which the president, Mr. P. Longmuir, will deliver his address. This will be followed by papers on "Modern Brass Founding," by Mr. H. S. Primrose; "The Training of Apprentices," by J. W. Horne, B.Sc.; "Coking in South Wales," by R. H. Greaves. In the afternoon a visit will be paid to the Dowlais Works of Messrs. Guest, Keen, & Nettlefolds, Ltd. A reception by the Right Hon. the Lord Mayor of Cardiff will take place in the City Hall at 7-30 p.m. Wednesday morning will be devoted to the reading and discussion of the following papers: "The Influence of Sulphur on Cast Iron," by Mr. H. I. Coe, M.Sc.; "Moulding a Water-jacketed Gas Engine Cylinder," by Mr. J. G. Robinson; "Pattern Making," by Mr. R. H. Schofield; "Moulding Sands," by Mr. A. B. Searle. The afternoon and evening will be devoted to visits to the Cardiff Docks and the Penarth Docks and hydraulic houses. On the Thursday a picnic has been arranged to the Wye Valley.

The Junior Institution of Engineers.—About 100 members of the Junior Institution of Engineers recently paid a visit to the works of the Marconi Wireless Telegraph Company at Chelmsford. Mr. Marconi, the President of the Institution, was unfortunately called away at the last moment to Clifden, in Ireland, where the high-power station of his company on this side of the Atlantic is situated. Mr. Marconi was to have delivered his presidential address, but for the above reason was prevented from doing so. Captain H. Riall Sankey, assisted by the officials of the company, conducted the party over the works, where the actual working of wireless telegraphy was seen and explained. The members of the Institution were particularly struck by the perfect organisation and administration of the works, and the ideal conditions under which the men of the company do their work. The visitors were entertained to luncheon by the kind invitation of the company, and during the afternoon a "Marconigram" was sent on behalf of the Institution by the chairman, Mr. Walter T. Dunn, to Mr. Marconi in Ireland, expressing regret at his enforced absence, and wishing him continued and increasing success.

RECENT ADVANCES IN BATTLE-SHIP DESIGN.*

BY NAVAL CONSTRUCTOR D. W. TAYLOR, U.S.N.

In October, 1905, Great Britain laid the keel of a battle-ship materially larger than any before constructed and differing much from its immediate predecessors, notably in the fact that the heavy turret guns, instead of comprising two calibres, were all of the heaviest calibre—12in.—and there was no intermediate battery of 6in. calibre, the only calibre carried being 12in. in the main battery and 3in. in the secondary battery or torpedo defence battery. This vessel, named the "Dreadnought," being constructed with unprecedented rapidity and under circumstances of unusual and, for Great Britain, unprecedented secrecy, was, largely for this reason, the best-advertised ship in the world. It has been the fashion since to call large battle-ships Dreadnoughts, though in England, where the fashion originated, the expression super-Dreadnought is much used now, and doubtless we shall soon hear of super-super-Dreadnoughts. While the "Dreadnought" herself has been thrown in the shade by the later vessels, some of which are more than 50 per cent. larger, she ushered in an era of world-wide competition in battle-ship building and rapid increase of size and power of individual ships.

Table I. shows the effective battle-ship tonnage on January 1st, 1912, of the eight leading naval powers, divided between completed battle-ships of the pre-Dreadnought type and vessels of the Dreadnought type, built and building. For the purpose of this classification, vessels having a main battery of all big guns, 11in. or more in calibre, are classed as of the "Dreadnought" type. None of the eight nations of Table I. is building battle-ships of any other type. Vessels over 20 years old are not included, so Table I. shows approximately the battle-ship tonnage completed or laid down from 1891 to about 1906 as compared with that completed or laid down from about 1906.

TABLE I.—*Effective Battle-ship Tonnage.*

Nations.	Pre-Dreadnought type built. Tons of displacement.	Dreadnought type built and building. Tons of displacement.
Great Britain	617,500	483,350
Germany	252,712	359,120
United States	334,146	221,650
France	286,005	92,368
Japan	191,698	41,600
Russia	122,250	158,000
Italy	97,500	85,620
Austria	74,613	80,000

Table I. brings out clearly the world-wide "speeding-up" in battle-ship building of the last few years. The figures for Great Britain and Germany make it clear why some people in Great Britain consider that country to have made a colossal blunder when she forced the pace by building a new and more powerful type of battle-ship. The result, of course, is to relatively reduce in value earlier battle-ships, as to which we see, in the second column of Table I., England had a much greater superiority over Germany than indicated in the third column for battle-ships of Dreadnought type. Incidentally, Table I. makes it clear why the United States is just yielding the place of the second naval power to Germany. Of completed battle-ships the United States even yet has more tons than Germany, but the latter country is building so many more tons that the United States will never regain second place unless there is a marked change of policy on the part of one country or of both.

Of course, the customary gauging of naval power by tonnage is not an exact method of determining fighting power, but there is no accepted method by which we can determine this except, perhaps, actual war. Even tonnage statistics are not strictly comparable. We know that we use two kinds of tons in this country, the short ton and the long ton. For measuring displacement of battle-ships there are virtually as many different kinds of tons in use as there are nations.

A freight steamer may be able to carry in cargo double the weight of her hull and machinery. Her displacement then may vary 200 per cent. from her empty displacement. A battle-ship has a much larger proportion of fixed weight, but carries a large removable or variable load in her coal, ammunition, stores, and water. Such weights may amount to 18 or 20 per cent. of the empty weight of a large battle-ship. It is the practice to include arbitrary amounts of consumable weights when fixing the legend displacement of a battle-ship, and, as the practice in this respect of the various nations varies, the designed or official displacement of a given battle-ship would be different in each country.

A battle-ship is a very complicated matter, a complete design being evolved by art as well as by science from many conflicting considerations. Perhaps the most salient characteristics bearing directly upon war efficiency are offensive power, speed and endurance, and defensive power. There are many other essential characteristics, such as habitability, strength of structure, stability in intact and damaged condition, seaworthiness, &c., but for present purposes we must largely take these for granted.

In making Table I. we adopt as the dividing line between the Dreadnought type and pre-Dreadnought types the characteristic of carrying a main battery of all big guns 11in. or more in calibre. The "Dreadnought" was by no means a wholly novel type. The name has been borne in succession by a number of British men-of-war, and, curiously enough, when we compare the "Dreadnought" of 1905 with her immediate predecessor completed in 1875 (just 30 years before the "Dreadnought" of the present day was laid down) we find that the "Dreadnought" of 1875, like her successor, was, when completed, the largest, fastest, most powerful, and most heavily armoured British battle-ship. Her main battery was uniform in calibre, consisting of four muzzle-loading rifles of 12·5in. calibre, mounted in turrets. She carried also six rapid-fire guns—called then quick-firing—of 2½in. calibre. The "Dreadnought" of 1905 carried a main battery uniform in calibre consisting of ten breech-loading rifles of 12in. calibre, mounted in turrets. She carried also 27 rapid-firing guns of 3in. calibre. Each of these "Dreadnoughts" had an armour belt extending from end to end; its thickness amidships was 11in. in each case.

Compare them how we may, the twin-screw, reciprocating-engined, 14-knot, 10,800-ton "Dreadnought" of 1875 shows remarkable similarity of type to the four-screw, turbined, 18,000-ton, 21½-knot "Dreadnought" of 30 years later. One naturally asks how it happens that in 1905, when making a marked advance in battle-ships, there was recurrence to the type of 1875, particularly as regards battery. The reasons, I think, are two-fold. In the first place, in 30 years the process of evolution had nearly completed its cycle and the battery was approaching again the type of a generation before. There are on a battle-ship but two really satisfactory locations for turrets carrying heavy guns. One is forward of the machinery spaces in the centre line of the ship, and the other is aft of the machinery spaces, also in the centre line of the ship. So we find successors to the "Dreadnought" of 1875 in the English Navy mounting usually four heavy guns in these locations. But there was a steady evolution from the half-dozen 2½in. quick-firing guns of the old "Dreadnought." The secondary battery grew into an auxiliary battery plus a secondary battery, so that in 15 years, or about 1890, we find British battle-ships carrying four heavy or main battery guns as before, but instead of a few puny quick-firing guns they carried ten or a dozen 6in. guns, protected behind armour, in addition to smaller guns still.

These 6in. guns, combined with four heavy 12-inch guns, remained the standard, one may say, for some ten years or so. In the "King Edward" class, designed about 1901, we find a change. Their immediate predecessors carried four 12in. guns, twelve 6in. guns behind armour and sixteen 3in. guns unprotected. The "King Edwards" carried four 12in., four 9·2in. in turrets, ten 6in. behind armour, and twelve 3in. unprotected. This was the first appearance of the 9·2in. gun upon the British battle-ship. The next British class—the "Lord Nelsons"—laid down in 1904, abandoned the 6in. gun. The "Lord Nelson" carried four 12in., ten 9·2in. in turrets, and fifteen 3in. unprotected. Here, then, we have two sizes of heavy turret guns, and it is quite reasonable to suppose that

* Abstract of paper presented at a meeting of the Franklin Institute, February 21st, 1912.

in time the 9·2in. guns would have grown larger until by natural evolution the all-big-gun one-calibre ship would have appeared.

But there was a second factor which accelerated the slow process of evolution. For 30 years, to my knowledge, it has been a truism of the ordnance officer that the gun is a weapon of precision. Indeed, the precision of heavy guns is astonishing. Twelve-inch shells fired from a modern high-powered gun and leaving the gun in exactly the same direction with exactly the same velocity may be expected in still air to strike a target 10,000 yards, or say $5\frac{2}{3}$ miles, away within a very few feet of each other. But, strangely enough, up to some ten years or so ago no navy appears to have realised the possibilities of the gun, or, at any rate, to have developed accuracy of shooting to an extent approaching anywhere near the inherent possibilities of precision of the gun. About the year 1900 there began a movement for improvement. It originated in the British Navy, but their first improvements were very soon adopted in the United States Navy, and both made rapid and remarkable progress. Telescopic sights were adopted and perfected. Formerly the gun sighter had to look simultaneously at his rear sight, his front sight, and the target. With the telescopic sight he has simply to look at the target.

Now it was found very early in the evolution of methods of fire control that the problem was very much complicated when it was attempted to handle simultaneously two different calibres of guns. Also, the largest guns were much more accurate at the longest ranges. Hence there arose a demand from gunnery officers for uniformity of calibre of heavy guns just about the time when, by a process of natural evolution, we were approaching this type. Accordingly we find the British "Dreadnought" and the American "Michigan," which was designed very soon afterwards, carrying 12in. guns and 3in. guns only, the intermediate calibres, which were 7in. and 8in. in America and 6in. and 9·2in. in Great Britain, having disappeared.

It is interesting to note that at once the process of evolution again began. The small guns were called the torpedo defence battery and were supposed to be of use only against torpedo vessels. But in England the 3in. guns of the "Dreadnought" were replaced by 4in. guns on her successors, and it is currently reported that the most recently laid down English battle-ship is to carry a torpedo defence battery of 6in. guns. In the United States the 3in. guns of the "Michigan" were followed by the 5in. guns of the "Delaware," and on the later vessels there is carried an improved

Year of laying keel	GREAT BRITAIN	GERMANY	UNITED STATES	JAPAN	FRANCE	ITALY	AUSTRIA	RUSSIA	Year of laying keel
1905	Dreadnought 1 vessel 17900 tons 12 inch guns 12 pounders	Hannover class 4 vessels 13200 tons [illegible] inch guns 6·7 inch guns	Vermont class 6 vessels 16000 tons 12 and 8 inch guns 7 inch guns	Satsuma class 2 vessels 19250 tons 12 and 10 inch guns 6 inch guns		San Giorgio class 4 vessels 9830 tons 10 and 7·5 inch guns 12 pounders			1905
1906	Bellerophon class 3 vessels 18600 tons 12 inch guns 4 inch guns	Nassau class 4 vessels 18500 tons 11 inch guns 6 inch guns	South Carolina class 2 vessels 16000 tons 12 inch guns 3 inch guns						1906
1907	St. Vincent class 3 vessels 19250 tons 12 inch guns 4 inch guns		Delaware class 2 vessels 20000 tons 12 inch guns 5 inch guns		Danton class 6 vessels 18400 tons 12 and 9·4 inch guns 12 pounders		Radetsky class 3 vessels 14500 tons 12 and 9·4 inch guns [illegible] inch guns		1907
1908		Thuringen class 4 vessels 21000 tons 12 inch guns 6 inch guns							1908
1909	Neptune class 3 vessels 20200 tons 12 inch guns 4 inch guns	Kaiser class 8 vessels 23000 tons 12 inch guns 6 inch guns	Utah class 2 vessels 21825 tons 12 inch guns 5 inch guns	Kawachi class 2 vessels 20750 tons 12 inch guns 6 inch guns		Dante Alighieri 1 vessel 19000 tons 12 inch guns 4·7 inch guns		Gangoot class 4 vessels 23300 tons 12 inch guns 4·7 inch guns	1909
1910	Orion class 5 vessels 23500 tons 13·5 inch guns 4 inch guns		Arkansas class 2 vessels 26400 tons 12 inch guns 5 inch guns		Courbet class 6 vessels 23467 tons 12 inch guns 5·5 inch guns	Conte di Cavour class 3 vessels 21500 tons 12 inch guns 4·7 inch guns	Tegetthoff class 4 vessels 20000 tons 12 inch guns 4 inch guns		1910
1911			Texas class 2 vessels 27000 tons 14 inch guns [illegible] inch guns						1911

FIG. 1.—BATTERIES OF BATTLE-SHIPS LAID DOWN IN 1905 AND SUBSEQUENT YEARS.

Cross wires in the telescope which to the gun sighter seem to be in the plane of the target show the point of the target where the shot will strike if the sighting is correct.

Methods were devised for increasing the rapidity of loading and for facilitating training and elevating guns so that, regardless of the motion of the ship, the gun could be kept always pointed on the target and could be fired as fast as loaded. Guns, of course, were fitted with sight bars adjustable for the various ranges and also to allow for wind, &c., but it was soon found that there were variables present which no sight bar could take account of. For instance, after a gun had been warmed up by firing a number of shots it would not shoot quite the same as when cold. Two charges from different lots of powder would not shoot alike. Charges from the same lot of powder, if of different temperatures when loaded, would not shoot alike. Careful and systematic endeavours were made to eliminate or reduce to rule the above and other variables liable to produce erratic shooting, and it was found in the end that the most hits were made if the sight bar was corrected as necessary from observations of previous shots. Hence the development of observation stations as high up as possible, so that the "spotters," as they are called, can follow the fall of shell at extreme ranges. Elaborate systems of communication were also developed, so that the fire control officers at the spotting stations could readily communicate necessary instructions to all guns.

type of 5in. gun about as powerful as the 6in. gun of ten years ago. Other nations which took up the "Dreadnought" type later never abandoned the 6in. gun. Hence we may say that, broadly speaking, on the average the type of battery of to-day is again that of 10 or 15 years ago, consisting of a number of heavy guns in turrets and a number of 6in. guns in broadside. The differences are that on the much larger ships two or three times as many heavy guns are carried and the 6in. guns are not so well protected, being regarded by many designers as useful against torpedo craft only. With the increase in size of torpedo craft and in range of the torpedo we may anticipate a demand for torpedo defence guns which will put torpedo vessels out of action at longer ranges, and probably for larger calibres which are more accurate at the longer ranges. The art of fire control has not stood still, and the problem of the control of a mixed battery is not so difficult as it was some years ago. While the only thing that may be safely prophesied is that present types will be developed into others, it seems reasonably certain that the evolution of the torpedo defence battery of to-day will be along one of two lines.

The torpedo defence battery will be made larger in calibre, given more protection, and relied upon for use in action against battle-ships, so that we will return to a mixed battery type, or the main battery will be relied upon for torpedo defence work and the torpedo defence battery will disappear.

In concluding what I shall say about armament I would invite your attention to Fig. 1, indicating by skeleton deck plans the main battery distribution of the most recent battle-ships of the principal naval powers. Broadly speaking, the heavy turret guns monopolise the commanding positions and the small guns have to be given what is left. Most nations, the United States among them, locate the torpedo defence guns below the heavy guns. They are thus better protected and easily supplied with ammunition, but are objectionably close to the water. Great Britain has hitherto located torpedo defence guns at the level of and above the heavy guns. It is much more difficult to carry 6in. guns thus than 4in. guns, and if it is a fact that England has come to 6in. torpedo defence guns it is very probable that the change in calibre will be associated with a change in disposition.

As to the heavy guns, the disposition, as shown in Fig. 1, is most varied. I have already mentioned that the only satisfactory locations for turrets carrying heavy guns are forward and aft in the centre line. Broadside fire is paramount under present conditions, as it is generally admitted that ships will fight broadside to broadside rather than end on.

A centre line mounting is the only one that permits a gun to be used with equal effect on each broadside. A gun mounted in the centre line forward can also be used forward and one so mounted aft can be used aft. A gun mounted in the centre line near the middle of the ship can be used, as a rule, for broadside fire only, and generally for rather a limited range only. Having in view the necessities of the machinery, it is difficult to provide satisfactory ammunition stowage for guns mounted near the middle of length of a ship.

As exemplified by the diagram of the "Michigan" in Fig. 1, it has been the practice in the United States "Dreadnoughts" to carry two heavy turrets at each end, thus having four turrets in the most satisfactory location. Additional turrets are located in the centre line. With two turrets at the end one must fire over the other. This American arrangement has had the flattery of imitation by nearly all foreign nations. Fig. 1 shows clearly that the latest battle-ships of nearly all nations have adopted this disposition.

It is seen from Fig. 1 that heavy turrets that are not placed near the ends in the centre line are disposed according to three methods. (1) On the broadside firing on one side only. (2) On the broadside firing through a large arc on one side and a restricted arc on the other. (3) In the centre line firing equally on each broadside.

The first arrangement has the serious drawback that a turret so mounted can be used on one broadside only. It is seen that the United States never adopted it for the heaviest guns, and England and Germany have abandoned it.

The second arrangement has the disadvantage that the arc of fire across the deck is usually very restricted—and more restricted, as a rule, upon the actual ship than upon the design. It has also the disadvantages, common to all large broadside turrets, that the opening in the deck for the barbette below the turret is a source of weakness of structure difficult to make good, and that the magazines below are much more liable to be exploded by torpedoes or mines than in the central location. With this broadside arrangement we find generally one turret on each side near the middle of the ship. On paper such turrets are generally indicated as firing from right ahead to right astern. As a matter of fact, it is not practicable in most cases to fire right ahead or right astern without serious damage to the ship from the blast.

The third arrangement has the advantage from nearly all points of view, except that when two turrets are used and it is necessary to raise one in order to permit train across the deck, it is slightly heavier than the broadside arrangements.

We see from Fig. 1 that a comparatively short time after the adoption of the all-big-gun type of ship many nations increased the size of these big guns. England went from 12in. to 13½in. in the "Orion," laid down in 1909. The United States went from 12in. to 14in. in the "Texas," laid down in 1911. Germany went from 11in. to 12·2in. in the "Thüringen," laid down in 1908, and there are rumours in the papers that she is about to increase again her big-gun calibre, and that other nations who have not surpassed 12in. are about to do so.

The introduction of a new calibre of heavy guns into a navy is a large undertaking and results in permanent complications as regards manufacture and supply of ammunition. I regard it as doubtful if the calibre of 14in. now used by the United States will be exceeded in the near future by any nation. Looking backward, it may be recalled that eight out of our first nine battle-ships carried 13in. guns of rather low power and that in 1899 we made a reduction of bore, adopting the 12in. calibre—of high-power type.

Before leaving the question of offensive power I will touch very briefly upon the torpedo battery of battle-ships. The torpedo is a weapon which cannot be ignored, but, being at best complicated, easily deranged, and erratic, it has never shown in practice capabilities claimed for it by its advocates. It is primarily the weapon of the torpedo craft, but battle-ships carry them too—from two to six submerged torpedo tubes being carried by the latest battle-ships. Torpedoes have been improved during the last few years, and with their increase in size and range they would now be a very formidable addition to the battle-ship's offensive power were it not for the fact that the increase in fighting range due to improvement in gunnery has been relatively even greater than the increased range of the torpedo.

The torpedo battery of battle-ships will continue to be a strong incentive to induce battle-ships to do their fighting at ranges beyond that of the torpedo, and naturally to prevent any recrudescence of ramming tactics in battle-ship actions. Ramming tactics became obsolete as soon as the torpedo became a dangerous weapon, more than a quarter of a century ago.

(To be continued.)

METHOD OF ADDING ALUMINIUM TO YELLOW BRASS.

THE very extensive use of aluminium in yellow brass castings at the present time has been instrumental in bringing up the question of the best method of adding it. The great benefit of aluminium in yellow brass has now been thoroughly demonstrated, and with the exception of goods, such as plumbers' brass goods, and valves, to stand pressure, it is almost exclusively used in making yellow brass sand castings. It renders the castings sounder and free from pinholes to a marked degree. The brass runs sharper, more pieces can be put on a gate, and the castings come out of the sand cleaner. Brass founders have fully realised these advantages. The natural method of adding aluminium to yellow brass is to introduce it into the brass just before pouring. This is the method generally used, but is open to the objection that the amount of aluminium used is so small that it is difficult to alloy it with the brass, and it is apt to float on the top of the melted metal and waste; and also that the aluminium causes the brass to "flare," on account of the heat generated in the alloying and is apt to waste spelter. This latter objection is not a serious one except when considerable aluminium is to be added; but the first objection is an obstacle when certain results are obtained.

According to "The Brass World," the best method of adding the aluminium to yellow brass is to make a rich alloy of zinc and aluminium by melting them together and breaking up into small pieces. Take the following: zinc 7½lbs. and aluminium 2½lbs. This gives an alloy containing 25 per cent. of aluminium. It is added to the brass just as zinc would be added, and to obtain any desired weight, simply take four times the amount of the alloy of zinc and aluminium. This alloy, by-the-way, is frequently called "aluminised-zinc." If, for example, it is necessary to add 2ozs. of aluminium to brass, take 8ozs. of the alloy; and then take 8ozs. less of zinc in the mixture. For ordinary work, however, it will not be necessary to take any account of the zinc as it will practically make up for the loss in melting. All that is necessary to do, therefore, is to add four times the amount of the aluminium needed in the form of the zinc and aluminium alloy. The use of this zinc and aluminium alloy instead of pure aluminium will prevent flaring and render it always certain that the right amount of aluminium is introduced into the brass. With the regular method of adding the aluminium alone, it is not positive that it all goes into the metal. For ordinary yellow brass work, from 2ozs. to 3ozs. of aluminium are used, and this means that from 8ozs. to 12ozs. of the aluminium and zinc alloy are required. If more is added, the brass becomes harder and is apt to shrink considerably. If less is used, then the full value of the aluminium is not obtained.

THE MAINTENANCE OF SUPERHEATER LOCOMOTIVES.

THE report of a Committee appointed by the American Railway Master Mechanics' Association to enquire into: (*a*) The best metal for cylinder and steam-chest bushings; (*b*) the best metal for valve and piston rings; (*c*) the best means of lubricating superheater locomotives, was presented at the annual Convention of the Association, held on June 17th. In order to obtain as many data as possible upon which to base its report, the committee issued a circular of enquiry to the members. An analysis of the replies indicates that the results obtained from superheater locomotives have been very satisfactory.

It appears that five years ago there were less than a dozen superheater locomotives operating in the United States, whereas at the present time there are about 2,500 locomotives in the United States and Canada having fire-tube superheaters. Minor difficulties have been experienced on a number of railroads; but the great advantages to be derived from the use of superheated steam, such as increased economy of coal and water, increased power, due to the absence of cylinder condensation, the permissible reduction of steam pressure combined with the use of larger cylinders—all obtained without material increase in the size or weight of boiler—lead us to believe that the use of superheated steam in locomotives will increase rapidly. This being so, it is of great importance to determine the metal best suited for use for bushings and packing rings on modern superheater locomotives, because the use of highly superheated steam increases the difficulty of obtaining proper lubrication, and thus the metal is subjected to more severe working conditions than are usually found with saturated steam locomotives. It is also important that we know the best means of securing proper lubrication, because the efficiency of lubrication has a direct bearing on the life of bushings and packing rings.

A metal suitable for use as cylinder and steam-chest bushings of superheater locomotives should be homogeneous, close grained, tough and of good wearing quality, combined with sufficient strength. It should be tough in order to resist wear, but at the same time it must be of such composition that it can be readily machined. Replies to the circular of enquiry indicate that Hunt-Spiller gun iron has been used on many railroads with excellent results. This is stated to be an air-furnace charcoal iron, and the process of manufacture, combined with proper chemical composition, seems to result in a metal which is well adapted for use with highly superheated steam. The analysis of this iron obtained by your committee is as follows: Silicon, 1·40 per cent.; phosphorus, 0·35; sulphur, 0·07; manganese, 0·49; combined carbon, 0·80; graphite carbon, 2·20. Replies indicate that this same iron has been used extensively for piston and valve packing rings on superheater locomotives with very satisfactory results, and that an iron of this character is the best metal so far produced for piston and valve packing rings of superheater locomotives.

The importance of properly lubricating cylinders and steam chests of superheater locomotives, especially those using a high degree of superheat, can hardly be overestimated, because if proper lubrication is not obtained many of the advantages derived from the use of superheated steam are offset by continual troubles from excessive cutting of bushings and packing rings, which keep the engine in the engine-house when its proper place is on the road. There seems to be a tendency to use too much oil in superheater locomotives, with the result that there is trouble from the oil carbonising on the cylinder heads, pistons, and steam passages. The deposit of carbon also tends to diminish the life of the metallic piston-rod packing, as it builds up in the stuffing boxes and under the vibrating cups to such an extent that the packing in a short time is forced to carry a part of the weight of the piston rod and piston head. On certain classes of locomotives, possibly those having pistons exceeding 24in. diam., it is considered by some advisable to lubricate the cylinder independent of the steam chest, but in most cases we believe better results will be obtained by eliminating the connection to the cylinders and delivering the oil to the steam passageway.

We do not approve of the arrangement of oil pipes in which the oil is delivered near the end of the steam chest, as in this case it is probable that part of the oil is lost in the exhaust, due to the difference in pressure between the live and exhaust steam. A number of roads report that when superheater locomotives were received from the builders oil was delivered to both ends of the steam chest and to the centre of the top of the cylinder; but this arrangement has since been changed so that the oil is now delivered into the steam passageway above the entrance to the steam chest, and the feed to the cylinder has been discontinued. The allowance of oil has also been reduced and it has been found that the locomotives are much better lubricated than formerly, and there is a marked diminution in the quantity of oil adhering to the cylinder heads, piston heads, and steam passages.

There can be no doubt of the advisability of using a good grade of mineral oil having a high flash point for locomotives using highly superheated steam, because the temperature of the superheated steam is sometimes as high as 600° Fah. A number of the roads state they have used valve oil having a flash point of about 520°, and also special superheater oil having a flash point of at least 585°, and in every case better results have been obtained from the oil having the higher flash point.

Tests have shown that a moderately high temperature has very little effect on the lubricating properties of a good grade of valve oil when the oil is protected by steam, but when the engine is drifting there is, in most cases, no steam in the cylinders, and the bushings are apt to become hot. There does, however, appear to be a difference in the results obtained on superheater and saturated-steam locomotives. When drifting the conditions are the same on both, but on saturated-steam locomotives the oil deposit on the cylinders is fluid and the condition of the oil does not appear to have changed; while on superheater locomotives the deposit is gummy and sticky to the touch. This difference may possibly account to a large degree for the rapid wear of piston rings and bushings occasionally experienced on superheater locomotives. When an engine is drifting a good deal with a closed throttle, there is a considerable vacuum in the cylinders and steam chests, and cinders may be drawn through the exhaust and dirt through the relief valves. This dirt may adhere to the gummy oil on the cylinder walls and convert them into a lap which will wear away the packing rings and piston heads very rapidly.

This theory explains the good results obtained on locomotives where the drifting throttle has been carefully used and is supported by analysis of the deposit found on the cylinders, which show the presence of cinders and dirt in considerable quantities. The remedy is obviously to obtain a quality of oil that does not make a deposit of this nature at the temperature to which it is exposed, and to provide means either by ample vacuum or by-pass valves, or by the admission of steam to prevent over-heating when drifting.

Many roads use a tandem type of metallic packing on account of the importance of preventing the blowing out of the lubricating oil, which might result in the cutting of the cylinder bushings. During the past year or two, several alloys have been tried that have given satisfactory results, and while the preferable mixture will vary with the type of packing employed, this question is not now a serious one. It is important to use a type of piston-rod packing which will stand up under the high temperature met with in the use of superheated steam, and considerable trouble has been experienced with packing that had proven satisfactory with saturated steam when this point had not been attended to. The melting point of the packing rings should be higher than the melting point of rings usually found on saturated-steam locomotives.

In conclusion, your committee feels that, in order to ensure satisfactory results in the operation of superheater locomotives, it is of the utmost importance not only to use the best metals for parts subjected to the action of superheated steam, but it is also important to take all reasonable precautions to obtain proper lubrication. When superheater locomotives were first placed in operation it was to be expected that certain difficulties would be experienced, but these difficulties have been overcome one by one and we believe that at the present time, with reasonable care in operation and with proper attention on the part of engine-house forces, superheater locomotives will be no more difficult to maintain than saturated-steam locomotives of the same classes.

ELECTRIC DRIVING OF TEXTILE MILLS.*

Description of the Large Power System of the Pacific Mills.

BY FRED A. WALLACE.

The principal object of this paper is to describe the power system which has recently been installed at North Lawrence, which supplies electric current at 2,300 volts for power and lighting to the cotton, worsted, and printing departments of the Pacific Mills. The Pacific Mills represent several textile industries located in North Lawrence, South Lawrence, Mass., and Dover, N.H., and employ nearly 9,000 operatives. The manufactured products are principally worsted and all-wool dress goods, printed and dyed cotton, worsted and silk fabrics. An addition is now being built at South Lawrence, containing 1,320,000 sq. ft. of floor space, and it will be, when completed, the largest print works in the world.

The entire Pacific Mills contain 6,168,000 sq. ft., or about 142 acres, of floor space and operate 404,360 spindles, 10,468 looms, and 48 printing machines. There are 181 engines and turbines of 30,000 h.p., 165 boilers of 36,000 h.p., and water wheels of 7,500 h.p. There are also 625 electric motors of 17,700 h.p., principally alternating current, all of which are General Electric, including those in process of installation. The different departments consume 10,000,000lbs. of wool, 20,000,000lbs. of cotton, and 85,000 tons of coal per year. The finished product of the printing department alone is nearly 2,000 miles per week of printed cotton cloth.

When the mills commenced to install more modern and higher speed machinery in place of some of its older equipment, more power was needed, and it was also realised that the old power apparatus was getting to the end of its useful life. These conditions necessitated material changes in the power system, and after making a study of the conditions, it was decided to build the Central Power Plant, which is one of the largest isolated steam turbine stations in the world devoted entirely to the textile industry, and to adopt the electric transmission. The design and supervision of the construction was assigned to Mr. Chas. T. Main.

In the old arrangement, there were at the Upper Mill two 28in. by 48in. 106 revs. Buckeye engines of 750 h.p. each, connected to four water wheels; also a double walking beam Corliss engine was geared to four other vertical water wheels. The jackshaft of both sets of water wheels was connected by belt transmission through the several floors of the seven-storey mill to different departments and by long lines of shafting and gearing to the print works. The displacing of these belts and shafts by electrical transmission made room for much extra machinery, besides improving general conditions of cleanliness and fire risks. A great many sets of large bevel and spur gears were also removed by this change, which increased the general efficiency as well as eliminating a great deal of noise and mechanical troubles. A Rice & Sargent cross-compound engine of 800 h.p. was removed from the Lower Mill. This load, as well as a large overload from the remainder of the power system, was transferred to the new central station.

About the time that the power house was being built, additions to the processes of manufacture were installed, so that much more power is required now than with the old arrangement. The new station is located on a three and one-half acre lot adjacent to the main line tracks of the Boston and Maine Railroad, about one-quarter mile from the Upper Mill, and sends current at 2,300 volts to four centres of distribution, the farthest of which is over two-thirds of a mile away. The plant consists of a building for the boiler and turbine rooms, and a separate coal pocket.

Fig. 1.—Cable System at the Pacific Mills.

Boiler Room.—The boiler house is 140ft. by 87ft., and is arranged with two rows of boilers and a 20ft. space between them for coal storage and a firing floor. The floor is on a level with the yard, and with the turbine room basement. In the boiler room are 24 72in. by 21ft. 6in. horizontal multitubular boilers arranged in six batteries of four boilers each, 12 boilers being on each side of the firing floor. The boiler tubes are 3½in. by 20ft. long, and the total heating surface of each boiler is about 1,900 sq. ft. The grate area is 36 sq. ft. The boilers are constructed for a pressure of 160lbs. on the inch. The steam leaves the boiler by a 4in. pipe and passes through Foster superheaters set in the rear of the combustion chamber before entering the main line for distribution. All are connected to a 10in. main steam header, from which steam passes to the different turbines and auxiliaries.

The steam is carried with as high a velocity as possible without an excessive drop in pressure in order to get the

* Abstract of a paper entitled "Power System of the Pacific Mills: Methods and Rules for, and Cost of Operation," read before the Boston Society of Civil Engineers, and reproduced from the Journal of the Association of Engineering Societies.

highest efficiency from the superheat, and averages 7,900ft. per minute. Feed water is furnished by duplex steam pumps from the condenser discharge at about 75° Fah. through an exhaust steam heater which raises the temperature to about 200° Fah. This heater condenses the exhaust steam from the feed pumps, condenser pumps, and engines, and an engine on exciter set, as well as the 75 kw. alternator engine.

The piping is arranged so as to avoid as far as possible any chances of serious trouble. The boiler feed piping is made so that any boiler may be fed with either hot or cold water in case of trouble with the other piping. For this purpose, a hot and a cold feed-water main are installed and so arranged that any or all pumps may be used on either, or part of them on each. The steam for the auxiliaries is taken from an auxiliary steam header, which is connected to the main header near each end. With these arrangements, steam may be shut off from any section of the piping at almost any time. The arrangement is also very convenient for testing, as the part of the plant under test may be separated from the rest of the plant. All pipes and exposed parts of the boiler shell are covered with 85 per cent. magnesia, 2½in. thick, and particular attention is given to radiation from heated surfaces and leakage through boiler settings.

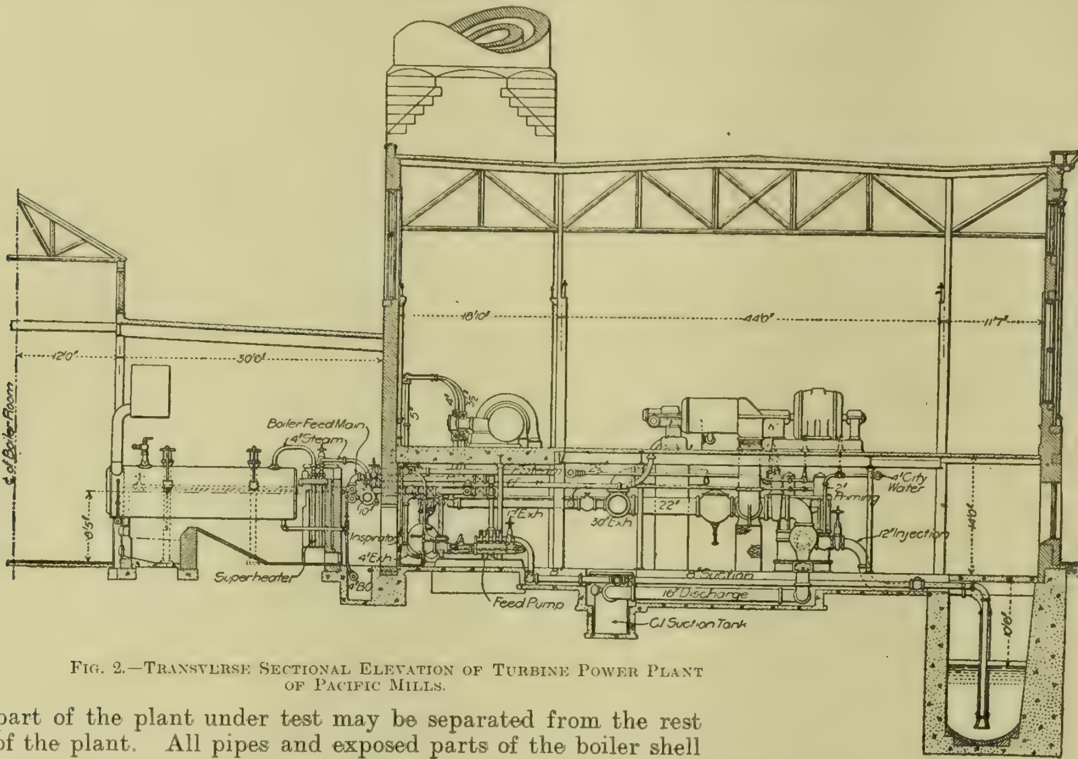


FIG. 2.—TRANSVERSE SECTIONAL ELEVATION OF TURBINE POWER PLANT OF PACIFIC MILLS.

Each group of boilers has a chimney 9ft. inside diam. by 200ft. high. The 12 boilers are connected to the two chimneys by a sheet-iron flue 6ft. by 10½ft. and a double damper which is controlled by a regulator and maintains a boiler pressure to within 1lb.

Turbine Room.—The turbine room is 126ft. by 79ft. with a basement of same size. The basement is 14ft. high, well lighted and ventilated, and contains all the boiler feed pumps, condenser apparatus, fire pumps, heaters, &c. Below the basement is a cistern 105ft. long, 10ft. wide, and 20ft. deep, which is connected with a 48in. penstock to the river about 1,000ft. distant. This well supplies water for condensing and all other uses about the station.

The station was first started in July, 1908, with three 750 kw. Allis-Chalmers steam turbine generating sets, and during 1909, a 3,250 kw. set of the same type was added. Additions to the various processes have called for more power, and a second 3,250 kw. turbine, similar to the other, has been installed during the summer of 1911 to replace one of the 750 kw. machines. The machine displaced is to be taken to another part of the mill system where small units could be advantageously used.

As the station now stands, it contains two 3,250 kw. and two 750 kw. steam turbines with jet condensing outfits, two motor-driven exciter sets, one steam-driven exciter set, and one 75 kw. engine-driven alternator with exciter. A small motor-driven centrifugal pump furnishes all pressure water for the station. The steam turbines are of Parsons reaction type, running 1,800 revs. per minute with 150lbs. boiler pressure, 125° Fah. superheat, and 27in. to 28in. vacuum. The condensing water after passing the jet condensers is returned to the river through a 48in. penstock and has been raised in temperature 15° or 20° Fah. The river water is nearly 32° during several months in the winter and reaches a maximum of 85° Fah. in the summer.

The turbo-generators are cooled by air supplied through a shaft extending above the roof next to the chimney. In this shaft are 12 bags, each 26ft. long and 22in. diam., and made of cotton cloth of a suitable weave to admit plenty of air and to filter out all dust. These bags are cleaned every three months, and about six quarts of material collected, besides that which is fine enough to escape during the cleaning process. This form of filter is very successful and is an absolute necessity for this dusty locality.

All alternating current in the plant is generated three phase, 60 cycle, and 2,300 volts. The switchboard controls all the generators and feeders. There is a panel of the switchboard for each exciter, one for each alternating-current generator, a total load panel, and one panel for each main feeder circuit. The power from it is distributed in large blocks to the various groups of mills, where it is further subdivided into smaller feeders about the mills. The large power feeders to upper and lower mills are really tie lines between stations, as one of these already has generators installed and the other will have in the future.

The output of each generator is measured by an integrating watt-meter, so that the total energy generated is known. Then each feeder circuit has its integrating meters so that the power sent to each group of mills is known. The power used for driving the motor exciters, coal handling, pumping, lights, &c., about the station is also metered. Each circuit is also equipped with indicating meters so that the instantaneous load and current may be obtained.

The current is sent from the station at 2,300 volts through lead-sheathed cables in vitreous conduits underground to four main divisions. (1) Upper mill power and lights, which is for cotton mill and old print works. (2) Yarn mill lighting, which is for cotton spinning. (3) Lower mill power and light, which is for worsted and woollen manufacture. (4) The new worsted power and lighting.

Coal Pocket.—Coal is stored in a concrete pocket 210ft. by 52ft. holding 5,000 tons, with a storage depth of 20ft., which is reached by a trestle from the Boston and Maine tracks. Cars are pushed up this trestle and dumped either into a main pocket or an auxiliary pocket. The floor of the main pocket is 10ft. below the yard level and that of the auxiliary pocket at the yard level. The purpose of the auxiliary pocket is to be able to handle coal by automobiles to the boilers if any accident should happen to the regular coal-conveying system. A 6in. pipe from the fire system is connected by a valve to the bottom of the coal storage so that, in case of fire to the coal, the whole area can be flooded as a last resort. The coal-conveying system is a monorail grab bucket, travelling at about 400ft. per minute and carrying 2,000lbs. The length of the average haul is about 350ft. The working capacity of the bucket is about 12 tons per hour, allowing for weighing each load. This system is proving satisfactory and one man handles all the coal at a cost of less than one penny per ton, including labour, repairs, supplies, and electric current.

2,300 Volt Transmission System.—The duct system is composed of multiple duct vitrified tile conduits laid in a concrete casing in the earth. The main part of this system near the power house has 22 ducts. They are laid up only two ducts wide so that each duct has at least one side exposed to the surrounding earth. This was done so as to avoid any chances of

overheating cables on the interior of the system during the long period of steady load, lasting practically all day.

All the cables for transmission from the power house are varnished cambric insulated for the standard of 5,000 volts working pressure, and have the three conductors under the same lead sheath. The main cables are all either of 3/0 B. & S. or 4/0 B. & S. size. The large circuits are made up by connecting several of these in parallel at the ends, at disconnecting switches. With this arrangement, should a cable fail, it could be cut out and repaired later. This arrangement of disconnecting switches also makes a very easy method of disconnecting the cables for testing them.

Tests of the insulation of all cables are made each month, and the insulation resistances plotted for record. These tests are made with a Fisher testing set, fitted with a very sensitive galvanometer. These records are considered very valuable as we expect to be able to follow any deterioration of the cables and anticipate any trouble on the transmission cables.

Upper Mill Yard.—The current from the main power station is received near the centre of the yard at a transformer station in power and lighting transformers and is there reduced to 550 volts for power and 115 volts for lighting before reaching the bus-bars of the distributing switchboard. At this station are three transformers, each 800 kilovolt-ampere, for power, and three transformers, each 100 kilovolt-ampere, for lighting—all being water cooled. At another small substation in the yard there are three other lighting transformers, each 100 kilovolt-ampere.

Small auxiliary transformers, each 15 kilovolt-ampere, are connected for light and power when required for overtime work. The secondaries of all these transformers connect to the distributing switchboard for this yard located in the next room, at what is locally known as the west wheel pit. This switchboard also controls all of the output from the water power at the upper mill.

In the main mill cotton department there are good examples of group, four frame, and individual motor drive installations. The first installations of motors were all arranged to drive groups of machinery through short lines of shafting. This type of drive was admirably fitted for use in this cotton department where much of the shafting was already in place and required no changing. Later, when some new twisting machines were installed and the motor for driving four frames by belts direct from the motor had been developed, some of this type were installed.

There are 36 pickers driven by 5 h.p. or 7½ h.p. motors belted directly to the machine beaters. In making this change a large amount of shafting was removed from the picker room, benefiting efficiency, appearance, and fire risk. The increase in the efficiency of this particular drive was surprisingly large. The motors for these pickers were mounted on the stand which formerly carried the countershaft for the machines. No trouble has ever been experienced with these drives.

Water Power at Upper Mill.—The water power is developed in two places, east and west wheel pits, each having two 39in. and two 36in. Hercules wheels, direct connected to generators. That for the east pit is of 800 kw. capacity, and that for the west pit 600 kw. Current is delivered to the switchboard by these generators at 550 volts. Although there are four wheels connected to each of these generators, it is customary to run only two wheels on each, except at times of high back water and consequent low head.

The Pacific Mills at these two wheel pits have the privilege of using, during 16 hours a day, water at the rate of 25 mill powers. A mill power is an arbitrary unit varying in different localities, and in this particular case is the right to draw water at the rate of 30 cub. ft. per second at 25ft. head. This is equivalent to about 85 h.p. theoretically. Thirty feet gross head is to be had most of the year, although in the worst freshets this has been reduced to 6ft.

As the generator shafts are slightly lower than the highest known river level, extra precautions would have to be taken to protect them during severe freshets; as freshets which would wet the generators would probably occur once in 50 years, it was thought best to take the small risk of trouble from freshets and avoid any complicated construction in order to arrange the plant so as to be safe from these maximum freshets.

When the electric power was being installed, due to more rapid progress in the installation of textile machinery than was expected, the electric load greatly exceeded the generating capacity, as all the generators were not ready for service. The power factor at the time was low, being about 60 per cent. There were at that time many motors on the line which had only a small part of their load of machinery ready to run. The 600 kw. generator was erected, but the wheels were not ready. This generator was put on the line and run as a synchronous condenser, doing no work, simply floating in the circuit, carrying at times 50 per cent. current overload, and thus raising the power factor on the system so that the other generators could carry more power load. No trouble was experienced in running this generator in this manner and very satisfactory results were obtained. When the wheels were ready, the coupling bolts were put in and the unit put into regular service.

The east pit is in a different room and not visible from the west pit, where the switchboard is located. The east pit generator is controlled from the board by the regular attendant, who has only his instruments to go by and an arrangement for indicating the gate opening of the wheels. No difficulty has ever been experienced from this arrangement. An oiler at the east pit looks after the bearings, &c.

One very marked advantage of having these wheels connected to generators which run in parallel with the rest of the system is that they can be used for supplying power to any part of the system for night work. As the water can be used 16 hours per day without extra cost, the water power can supply power to departments running a few hours overtime very cheaply.



FIG. 3.—VIEW OF BOILER HOUSE.

Yarn Mill Yard.—Only the lighting load of this mill is carried by the new plant, the power still being generated by the Corliss engine, which is in good condition. Provisions have been left for changing over the power if it should be desirable in the future.

Lower Mill Yard.—The lower mill, or worsted department, is situated two-thirds of a mile from the power house which supplies both power and lighting current. Some engine power and water power with belt and gear transmission is still being used at this yard. These drives will be replaced to a great extent by electricity when the conditions are suitable to make the change. There is now an electric load of 1,600 kw. This mill has a transformer house similar to the one at the Upper Yard, except that there is now no generator controlled from the switchboard. The transformer house contains three transformers for power, each 625 kilovolt-ampere, and three for lights, each 110 kilovolt-ampere. Other small transformers are located about the plant. The switchboard is in the basement adjoining the transformer house. It is designed so that generators can be controlled from it in future, if desired. All

the motors in this yard drive groups of machines through belts and shafting. As in the Upper Mill yard, all motors are wound for 550 volts, and open wiring is used from the switchboard to the motors. The same metering scheme is carried out as at the Upper Mill.

New Worsted Mill.—The new worsted mill is driven entirely by electric motors of 2,300 volts. There are no small motors and conditions are ideal for the use of a high voltage equipment. This is the latest and most up-to-date installation and will consume about 3,500 h.p. The power wiring is all run in conduit, especially protected, making a very efficient form of distributing power. The smaller wires required and also absence of transformers about offset the extra cost of installing this 2,300 volt work as compared with that for 550 volt.

This mill has many group drives and four frame motor drives. In the four frame drive, one motor suspended from the ceiling drives four machines without requiring any shafting, the motor shaft being extended to carry two pulleys at each end. The four frames are set so that the tight pulley of each lines up with one of the pulleys on the motor. There are 28 of these drives where the motor runs 1,200 revs. per minute for the frame spinning, and 20 running 900 revs. per minute for the twisters. All are 25 h.p. motors. These motors are started by throwing them directly on the 2,300 volt line, there being no compensator or other starting device, except the automatic oil switch. The motors are squirrel-cage type, with silver soldered rotors. Started in this manner, they create no more disturbance on the line than starting an ordinary 100 h.p. internal resistance motor with its usual shafting load.

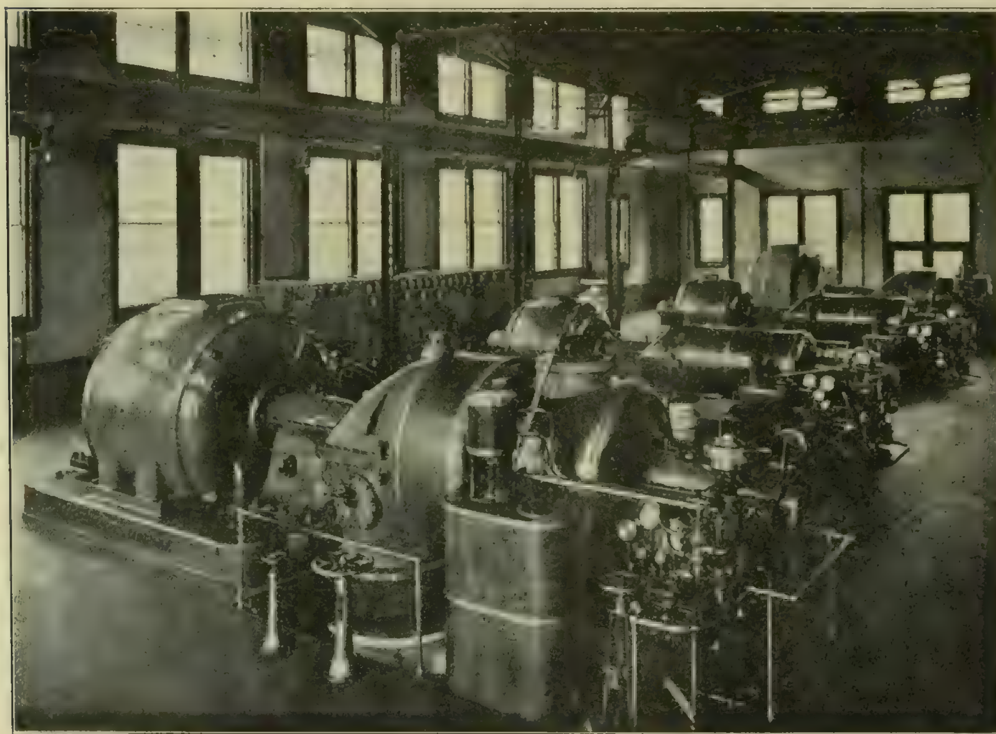


FIG. 4.—VIEW OF TURBINE ROOM.

Throughout the power wiring in the mill, junction boxes have been used at switches and motors so that any piece of apparatus may be quickly removed from the circuit and replaced without having to break and remake permanent splices, all connections being made with lugs and nuts on small tablet boards.

Auxiliary Power for Night Use.—The 75 kw. alternator mentioned in the turbine room is used for supplying the current for the yard lights, which are on all night, and for such other small uses as may be required. In order to make this operation as simple as possible, and at the same time avoid exciting the large transformers, a separate or auxiliary transmission circuit was installed for this set. This is so arranged that the whole may be run in parallel with the rest of the plant, or the 75 kw. set and its feeder circuit and transformer equipment run entirely separate from the main circuits. The latter is the normal operating condition. Under this condition the set takes care of itself, except that the night man inspects the bearings, oil supply, &c.

Load Connected.—There is at present a connected load on the electric power system of about:—

Lighting.

Incandescent lamps, 16 c.p.	14,600
Arc lamps, 6 amp. A. C. enclosed	187
Cooper-Hewitt mercury vapour lamps	360

Power.

Induction motors, 224, totalling 9,548 h.p.

Methods of Metering Power at the Station.—The four different main circuits all have total load integrating wattmeters as well as having wattmeters for the different departments on these circuits. The power-house switchboard has 17 panels, five of which are for distributing outside of the station, one distributing for the station, one regulator panel, five generator panels, and five exciter panels. The output of the station is known daily from the integrating meters on each generator, and this in connection with the coal consumed gives the most desirable operating item, pounds of coal per kilowatt-hour.

All distributing switchboards have curve-drawing wattmeters on the different circuits leading to manufacturing departments, and by these the weekly records are kept of manufactured product and power required. Indicating wattmeters are also placed on every distributing circuit so that power required at any time can be noted. The records are very desirable and supersede the older methods of indicating the steam engines. These records from the curve-drawing meters are very interesting, as they show the character of the loads of the various departments and also indicate how well the machines are kept in service. These curves show some surprising information as to machines being stopped before the regular time.

For further information, an ammeter is placed at every motor and this allows any person to see at once any change of power due to temperature, humidity, tight belts, systems of oiling, machinery out of level, or any change of quality or kind of material manufactured. It also furnishes a very convenient way of making tests on the power to drive machinery under different conditions. The results obtained in this manner are probably not as accurate as could be made by more elaborate tests, but are close enough. Then, too, tests which can be made easily and quickly, even if only closely approximate, are more apt to be made than tests which require considerable preparation.

Reduced to a percentage basis, the following is the manner in which the power generated at the steam turbine station is used:—

	Per cent.
Upper Mill, Power	46·6
Upper Mill, Lights	2·6
Lower and New Worsted Mills, Power	47·0
Lower and New Worsted Mills, Lights	1·9
Yarn Mill, Lights	0·3
Station use	1·6

Method of Operating.—The success of operating is due to care, watchfulness, and attention to small things, which makes it possible to foresee and prevent what might be serious accidents. Any trouble in the power house, or generating systems, which would cause loss of production in any of the manufacturing processes is considered a serious offence by those who are responsible. In the economical operation of the station much attention is given to the burning of fuel. The boilers are all hand fired, and an attempt is made to produce smokeless combustion. Samples of the gases are frequently taken and an analysis showing 12 per cent. CO_2, 7 per cent. O, is considered good practice. The load factor of the station is practically 33⅓ per cent., and although the load is quite con-

stant for $5\frac{1}{6}$ hours in the morning and 5 hours in the afternoon, it starts and stops very abruptly, which makes it difficult to manage the furnace fires economically at these times. All fires are banked at night, except those required to run overtime work on the regular lighting night circuits. All the ashes are weighed before being taken from the boiler house and the percentage of ash entered on the weekly report. Every carload of coal is sampled and a chemical analysis made for fixed carbon, volatile matter, ash, moisture, and B.T.U., and much attention is given to this record and its comparison with power-house results.

The steam pressure is controlled by damper regulators which also serve as a guide for firing, as the fireman practically works to this regulator and when the steam pressure drops even a fraction of a pound the damper starts to open and all the firemen together either level their fires or put on fuel in accordance with our alternate system of furnace control. This is on similar lines to modern steamship practice, except that, with their unusually steady load, they can set a gong to ring at definite intervals, at which every fireman does certain work on his furnaces. The burned gases after passing through the boiler tubes escape directly to the main flue at a temperature of about 475° Fah. There is no economiser.

There are now four firemen and a boss fireman on duty day times, each fireman firing four 190 h.p. boilers. There are three firemen on night times. Two of these men clean the fires of 14 boilers, while the third man cleans two boilers and is responsible for the station.

In any large power system it is very important that the generator speed be correct. We check the speed each day to keep the cycles correct, as the governor is changed each time the generators are phased together. In order to ensure correct frequency for the system, the spindle speed for 56 hours and also for five-minute intervals is kept on daily and weekly records.

The help for the turbine room consists of a chief engineer, who also has other duties outside the station, two operating men, one oiler for auxiliary apparatus, one cleaner who is also a spare fireman. The electric motors are started and stopped by electricians and helpers, each man attending to about 800 h.p. of motors. They are allowed 15 minutes to get everything running and then take two ammeter readings before leaving this department to attend to other duties. During the remainder of the day these men trim arc lights, repair wiring, install any new work or make any changes in the lighting or power equipment which may be necessary; they also attend to fire alarms, danger signals, and watch-clock system, and all repairs and maintenance. No one outside the electrical department is allowed to start or stop a motor unless life or property is in danger. This arrangement is found to give better results than the previous one where the mill overseers and foremen started and stopped the motors. With the attention we give it, the electric drive has proven dependable and successful.

Cleaning and Inspection.—The motors and switches are cleaned by compressed air weekly or semi-weekly as location demands, weekly for all departments in the mill and print works, except carding, pickers, shearing and nappers, which are cleaned semi-weekly. Compressed air at 80lbs. pressure is piped over the entire area occupied by motors, and a valve and quick-connecting coupling located at each motor. This same air supply is used also for repair tools, &c., when required. The air is used through a special nozzle which mixes room air and compressed air together and in so doing reduces the final jet pressure and also has a tendency to dry the air. A sharp jet of air will possibly injure the windings and is especially dangerous when accompanied by moisture. This special nozzle gives much lower velocity than the initial pressure would give, and at the same time gives a much greater volume of air. The generators are cleaned every three months, except the enclosed ones, which are supplied with filtered air, and these are cleaned about once a year.

A rigid system of inspection, including everything pertaining to electric generation and transmission, as well as elevators, fire risk and steam plants, is made weekly and is found to be of much importance in maintaining high efficiency. Inspectors have definite territory to cover and each one signs weekly reports which are kept on record. As an example, the inspectors for the motors take the temperatures, inspect all wiring and connections, switches, oil in bearings, cleanliness and general conditions and also read the ammeters.

Records.—A system of weekly reports is kept on file, which gives daily and weekly operating figures on all important items about the different power stations, and includes current generated, weight of coal and ashes, temperatures, pressures, oil and waste, labour of operating and repairs, supplies, division of costs, &c. A complete set of curves is also kept of these items, which show at a glance the comparison of any week and year. These figures are inspected each week by the chief engineer of the plants and the author.

Tests.—The acceptance tests of 3,250 kw. turbine at 100 per cent. load was 15·40lbs. of steam per kilowatt-hour, with 150lbs. boiler pressure, 125° superheat, 28in. vacuum with barometer at 30in. and condensing water at 70°. At other points the steam used was, 50 per cent. load, 17·83; 75 per cent. load, 15·50; 125 per cent. load, 15·46; and 140 per cent. load, 15·84.

Tests on the 750 kw. turbines under the same conditions gave for 75 per cent. load, 18·92lbs.; 100 per cent. load, 17·84lbs.; 125 per cent. load, 16·63lbs. steam per kilowatt-hour.

The auxiliaries, including condensers and feed pumps, use about 12 per cent. as much steam as the main unit. This test was made with the 3,250 kw. turbine delivering 3,810 kw., two condenser pumps, one feed pump, and the Holly drip return system constituting the 12 per cent.

During nights and Sundays, the 75 kw. lighting set, the 50 kw. exciter set, which is used for charging electric automobile storage batteries, and a boiler feed pump are run, and this load, together with the loss due to banking and cleaning fires, brings the weekly coal consumption to 2·3lbs. of coal per kilowatt-hour for the total current generated.

The station is operated at present at 3,600 kw. As this is only about 65 per cent. of its past rated capacity, the economy is not as high as it might be. Within the next few months this load will be increased to about 6,100 kw. The station now has a normal capacity of 8,000 kw.

Operating Costs.—The following figures are for cost of operating an average week on 3,600 kw. These are the conditions under which we have been operating for the last year:—

Turbine-room labour, 5 men, and superintendence	$99·85
Boiler-room labour, 8 men	99·15
Fuel, at $4·25 per long ton in pocket	880·00
Oil, waste and supplies and repairs	37·05
Total operating expenses per week	$1,116·05

During the week, 204,780 kw.-hour are generated, giving a cost per kilowatt-hour of 0·545 of a cent. Within the next few months the load will be increased, due to the putting into service of all of the new worsted mill, to about 6,100 kw., giving a weekly output of approximately 340,000 kw.-hours per week. At this time, the normal operating condition will be to run the two large turbines, leaving the two smaller ones as spares. To operate the station under these conditions will cost:—

Turbine-room labour, 5 men, and superintendence	$99·85
Boiler-room labour, 9 men	108·95
Fuel, at $4·25 per long ton in pocket	1,483·25
Repairs and supplies	58·60
Total operating cost per week	$1,750·65

Operating cost per kilowatt-hour $= \frac{\$1,750·65}{340,000} = 0·515$ of a cent.

The station as it now stands with 8,000 kw. normal capacity of generators, cost, with land and everything up to and including the switchboard, a little less than $90 per kilowatt. Figuring the fixed charges on this at 11 per cent., we get:—

$$11 \text{ per cent.} \times 720,000 = \$79,200 \text{ per year.}$$

$$\text{or } \$79,000 \div 52 = \$1,523·08 \text{ per week.}$$

With station generating 340,000 kw.-hour per week, the fixed charges will be $\frac{1,523·08}{340,000} = 0·448$ cents per kilowatt-hour.

The total cost then per kilowatt-hour at the switchboard, for the 6,100 kw. load on the plant, will be :—

Operating expenses per kilowatt-hour ...	0·515 of a cent.
Fixed charges per kilowatt-hour	0·448 of a cent.
Total	0·963 of a cent.

The same figures, if this plant should be operated at its full capacity of 8,000 kw., as is quite customary in textile mills, would be :—

Operating charges per kilowatt-hour ...	0·501 of a cent.
Fixed charges per kilowatt-hour	0·340 of a cent.
Total cost	0·841 of a cent.

Analysing these costs for the operating conditions of 6,100 kw., it is found that in percentage of the total cost :—

	Per cent.
Labour is	6·4
Fuel is	45·5
Repairs and supplies	1·8
Fixed charges	46·3

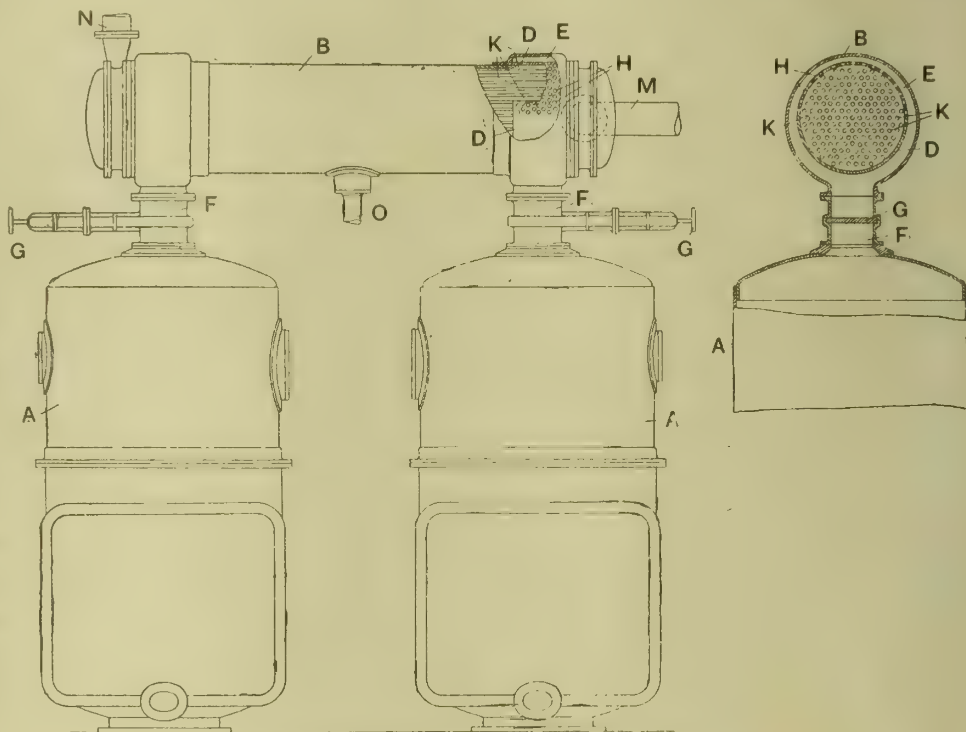
These figures plainly show that the two items from which any great saving may be expected are : (1) Less fixed charges ; (2) better fuel economy. We can also calculate how much more expensive and efficient apparatus we could afford to install to help out the fuel charges, remembering, however, that the more complicated apparatus invariably requires more expense of repairs and depreciation. The principal object in view in the design and operating of this station has been simplicity and reliability, and these have been obtained. Many of the requirements which are supposed to make for refinements in efficiency have been omitted, particularly in the boiler-room, where simplicity was especially desired. We prefer to operate a boiler plant as far as possible without many of the automatic devices on the market, as without these there are less parts to get out of order.

When the old mills were changed from engine to motor drive, a great amount of shafting and belting was removed, and this in itself is one of the motor's best recommendations, not mentioning flexibility of service, ability to check power required at any time, and increased production, due to more uniform speed. We have no accurate way of knowing whether the total power of the mills is more or less with the electric driving than with the old system, but probably the losses in one system would about balance those in the other. It is of interest to mention that, in these days of high economy, we are only realising 10 per cent. of the energy in the coal which we burn at the power-house, on the pulley of a machine in the mill.

WEIR'S MARINE EVAPORATING AND DISTILLING PLANT.

INSTALLATIONS of evaporating and distilling plants for use on board ship may comprise one or more evaporators. It is common practice for two evaporators to be arranged side by side with a single condenser placed alongside them, the condenser being of the vertical cylindrical type with vertical tubes. The steam evaporated from the sea water in the evaporators passes from the latter through their uptakes to a common vapour pipe, which is arranged above the evaporators, and is led downwards to the distilling condenser. As the available engine room floor space is often very limited, especially in warships, it is desirable to reduce as much as possible the floor space required by such plant, and with this object in view, Mr. William Weir, of Messrs. G. & J. Weir, Ltd., engineers, Cathcart, Glasgow, has designed and patented the construction illustrated herewith, which consists in brief in an arrangement and combination of elements according to which a single distilling condenser is arranged horizontally above a pair of evaporators and is connected thereto by short pipes or passages controlled by sluice valves. The evaporators are of the Weir type, in which the vertical height is considerably less than is usual for a given duty, and the sluice valve arrangement allows of the condenser lying close to the top of the evaporators so that the total height of the plant need not be much, if any, greater than is now usual for plant of equal evaporative capacity.

Referring to the illustrations, A A are the two evaporators and B is the condenser, which latter is of the cylindrical tubular type. The shell of the condenser, at or near its two ends, is swelled as shown, and a cylindrical plate D is riveted to the shell at this swelled portion so as to form an annular chamber E between the plate and the shell. Each evaporator is arranged to communicate with one of these annular chambers by means of a short coupling piece F which communicates on the one hand with the steam space in the evaporator and on the other hand with the annular chamber E. The flow of steam through each of these coupling pieces is controlled by means of the sluice valve G. Perforations H are formed in the upper portions of the plates D, which perforations serve to admit to the interior of the condenser the steam which rises from the evaporators through the coupling pieces F and the annular chambers E. The steam is condensed on the exterior surface of the tubes K, cold water being circulated through the tubes in the usual manner. M indicates the circulating water inlet and N the circulating water outlet.



WEIR'S MARINE EVAPORATING AND DISTILLING PLANT.

O is the air pump suction pipe which is connected to the bottom of the condenser at or about the centre of its length. The employment of steam-control valves of the sluice type allows of the coupling pieces F being of short length so that the condenser B is raised very little above the tops of the evaporators and, by employing evaporators of a type in which the height is less than usual, the total height of the plant can be kept quite moderate. As the steam is admitted to the interior of the condenser at the top and at the ends, and as the air pump suction is at the bottom of the condenser and midway between the ends, and as, moreover, the steam is admitted to the condenser through a large number of holes, the flow of steam over the cooling surface is fairly uniform, and the condensation is very well distributed over the cooling surface, thus allowing a condenser of minimum cooling surface to be employed. The steam in passing through the annular chambers E and through the perforations in the plates D tends to deposit on these plates and on the swelled portion of the condenser shell any particles of brine which may have been carried up with it from the evaporators. Any brine so deposited drains back into the evaporators ; and the apparatus is therefore useful in preventing or reducing the admission of salt to the interior of the condenser.

LOW WATER TESTS OF LOCOMOTIVE BOILERS.

AN interesting test was made under the direction of Prof. W. F. M. Goss, on June 20th last, to ascertain the effect of low water on two full-size locomotive boilers, one fitted with the Jacobs-Shupert firebox and the other with the ordinary radial stay firebox. In the Jacobs-Shupert firebox the usual arrangement of flat sheets supported by stay bolts is abandoned except in the front sheets and door sheets. The side sheets and wrapper sheet are replaced by sets of channel-shaped sections riveted together with their flanges away from the fire as clearly shown in Figs. 1 and 2. These sheets are partially cut away in the water leg to permit of the water circulating around the firebox. All seams are submerged and no joints are exposed to the direct current of heat and gases. The construction, it will be obvious, is of exceptional strength, and this feature was brought out in the test under notice.

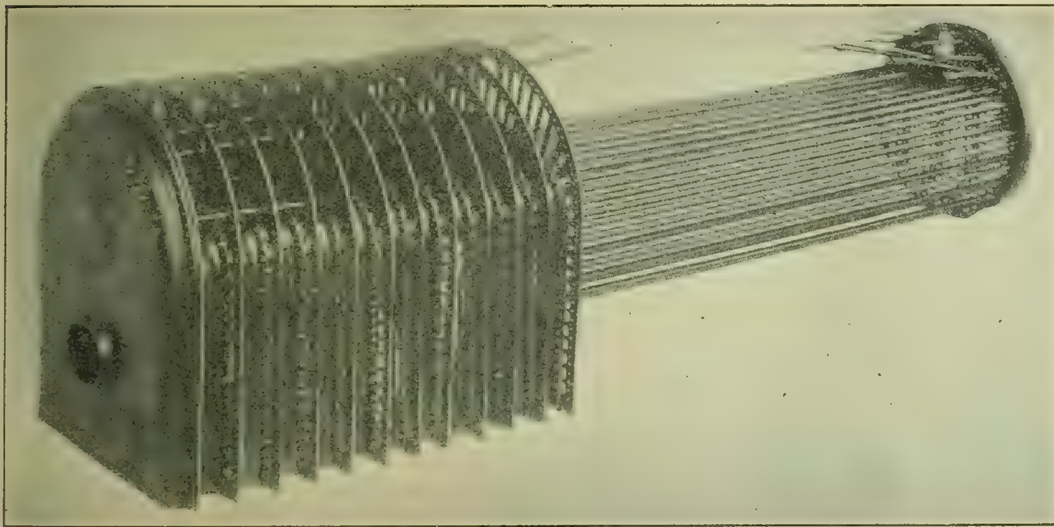


FIG. 1.—VIEW SHOWING ARRANGEMENT OF JACOBS-SHUPERT FIREBOX.

For the purpose of the test, the two boilers, which were designed for high-speed passenger service and identical in size and design with the exception of the fireboxes, were mounted in a field 50ft. apart, and were operated from a " bomb proof " located 200ft. away from the nearest boiler. Oil was used for fuel because of the danger to which a fireman shoveling coal would have been exposed. In the process of testing, each boiler was brought to a condition of operation closely approaching maximum power estimated to be 1,400 h.p., which is equivalent to that required to haul a heavy passenger train at 60 miles per hour. The supply of feed water was then shut off, but all other conditions were continued unchanged. The water level gradually fell, exposing the crown sheet and other portions of the heating surface to the full effect of the fire.

The boiler having the Jacobs-Shupert sectional firebox was continuously tested under these severe conditions for 55 mins. without developing any failure, notwithstanding the fact that the level of the water fell to a point more than 25in. below the crown sheet. The water gauge glass did not read below 25in. The test was then discontinued, because the small amount of water remaining did not evaporate sufficiently fast to supply the draught necessary to maintain the fire. At the conclusion of this test, the Jacobs-Shupert firebox was apparently in good condition, and ready for further service. A view of the firebox after the test is shown in Fig. 3. The boiler pressure varied between 215lbs. and 225lbs. on the inch for 27 minutes until the level of the water had reached 18¼in. Thereafter the pressure gradually fell, being 50lbs. at the end of 55 mins.

The ordinary radial stay boiler was then tested under conditions identical to those above described. After the test of the ordinary boiler had been in progress for 23 minutes, and the water level had fallen to 14½in. below the crown sheet, an explosion occurred. The crown sheet and the stays, which hold it in place, having become highly heated, pulled away from each other and released the pressure in the boiler. The discharge of steam was through the firebox and the force of the explosion, amidst clouds of steam and smoke, was sufficient to throw parts from the furnace in all directions for a considerable distance, and to lift the entire boiler, weighing 40 tons, several feet above its foundation. The damage to the boiler was such as to make necessary its reconstruction. Fig. 4 shows the condition of the firebox after the test, while Fig. 5 shows a photo view at the moment of the explosion. The steam pressure varied between 220lbs. and 230lbs., being 228lbs. when failure occurred.

A NEW DRY BLAST PROCESS FOR IRON FURNACES.

BY JOHN B. MILES.

SINCE James Gayley, in 1904, gave to the world the results of the operation of his refrigerating dry blast process, no marked deviation has occurred from the type of apparatus devised by him. The dry blast plant of the Northern Iron Company, built at Standish, N.Y., in the summer and fall of 1911, is of interest, since the process, here employed for the first time, differs in essentials from any other process that has been tried in practice. The cooling is done after compression in the blowing engines and sprays of water or brine, in direct contact with the air, accomplish the cooling instead of pipes in which the cold brine is circulated. The plant has a capacity of 20,000 cub. ft. of free air.

In the summer, when the brook water used is at 60° Fah., the compressed air will be cooled from 180° to 65° in the first stage, and from 65° to 28° in the second stage, reducing the moisture, if the blast pressure is 10lbs. per square inch, from 8½ grains to 1 grain per cubic foot of free or expanded air. Cooling after compression requires much less capacity of apparatus and less steam for its operation than any possible process in which the cooling is done before compression, as in the case of the various dry blast plants in this country and abroad. Since water from a natural source can be used for the greater part of the cooling, the size and cost of the refrigerating apparatus is much reduced, and with it the size and cost of the buildings. This process does not depend upon the use of unusually cold water, since its advantages can be demonstrated even with water of the temperature found in most of our rivers during the summer months.

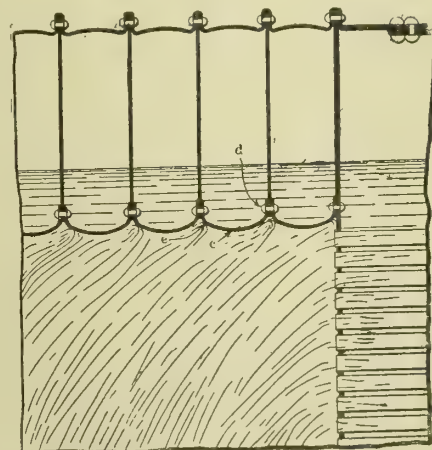


FIG. 2.—SECTION SHOWING METHOD OF STAYING JACOBS-SHUPERT FIREBOX.

The refrigerating apparatus, furnished by the Carbondale Machine Company, is of the ammonia absorption type and uses exhaust steam from the pumps, except for the aqua-ammonia pump. At this furnace, where there is an abundant supply of exhaust steam, the steam requirements of the dry blast plant are so small as to be practically negligible. The cooling chambers were furnished by the Carrier Air Condition-

ing Company, including the spray nozzles and piping, and the eliminators.

The compactness of the plant will be evident from the fact that the dry blast house occupies only 60ft. by 30ft. and is attached as a lean-to to the blowing engine house. The

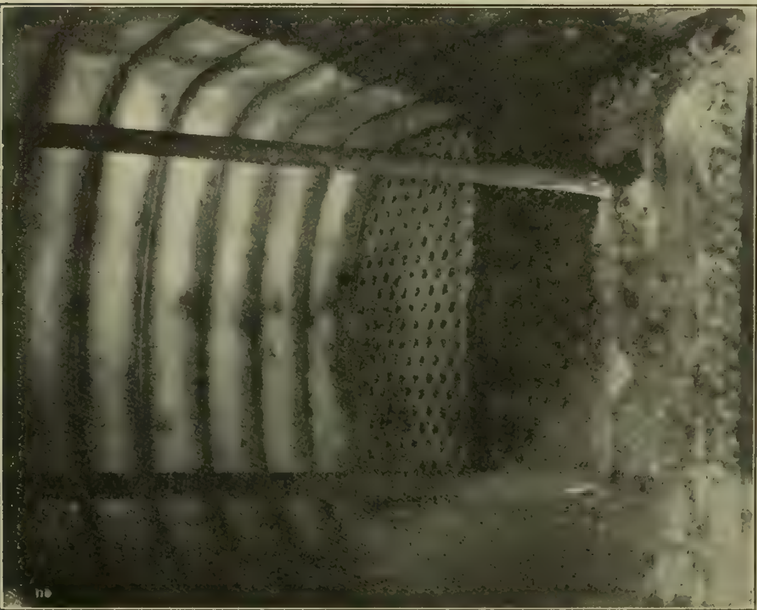


FIG. 3.—INTERIOR OF JACOBS-SHUPERT FIREBOX AFTER LOW-WATER TEST. (See p. 79)

pumps for the water and brine and aqua ammonia, the absorber generator, Baudelot cooler of the refrigerator apparatus and the evaporating are located on the first floor. The first and second stage coolers, the ammonia condenser, interchanger, weak liquor cooler, &c., are located on the second floor or gallery.

TABLE I.—*Daily Report of Operation of Dry Blast Plant, Day ending April 1st,* 1912.

Time.	Bustle Pipe.			Dried Air.				
	Dry.	Wet.	Grains.	Dry.	Wet.	Grains.	Pressure	Temp.
6 a.m.	......	......	......	75	51	1·36	12·5	36
7 a.m.	53	40	1·29	75	50·5	1·24	14	35·7
8 a.m.	51	39	1·29	74·5	50·5	1·29	12	36·3
9 a.m.	53·5	40	1·24	75	50·5	1·24	12·5	35·3
10 a.m.	53·5	40	1·24	75	50·5	1·24	13·5	37
11 a.m.	54·5	41	1·24	76	51	1·24	13·5	36·5
12 m.	55	41·5	1·39	78·5	52	1·21	11·25	34·5
1 p.m.	56·5	42	1·32	79·5	52·5	1·26	10·25	33·5
2 p.m.	......	......	......	79·5	52·5	1·26	10	34·5
3 p.m.	60	44	1·36	79	52·5	1·29	12	36
4 p.m.	60·5	44	1·29	79·5	52·5	1·26	11	34·5
5 p.m.	52	38·5	1·29	79·5	52·5	1·29	11	35
6 p.m.	......	......	......	78	52	1·29	12	35
7 p.m.	......	......	......	76	51	1·24	13	36
8 p.m.	55	41	1·29	75	50·5	1·24	14	36·5
9 p.m.	......	......	......	75	50·5	1·24	13·5	36·5
10 p.m.	54	41·5	1·32	74	50	1·24	12·5	36
11 p.m.	......	......	......	74	50·5	1·36	12	35·5
12 night	55	41	1·29	72	49·5	1·29	12·5	35·5
1 a.m.	......	......	......	70·5	48·5	1·26	11·5	35
2 a.m.	45	36	1·32	70·5	48·5	1·26	13·75	35·5
3 a.m.	43	34·5	1·26	69·5	48	1·24	12	35·5
4 a.m.	41	33	1·24	69	48	1·24	12	35·5
5 a.m.	......	......	......	68	47·5	1·29	11	36·5
11 a.m.	54·5	41	1·20	76	51	1·24	13·5	36·5

The air leaves the cold blast main and passes to the first stage cooler, which is 48ft. long. It then passes through a bend of 180° outside of the building, and returns through the second stage cooler, 36ft. long, to the cold blast main. These coolers are divided into compartments with an eliminator at the end of each, which arrangement uses the water efficiently, the air being reduced, in the last compartments of each stage, to within a few degrees of the temperature of the entering water or brine. From each stage the water or brine flows to a drum in which are floats controlling the drain valves. The water from the first stage passes to the suction well of the pumps, which furnish the furnace supply, and the brine from the second stage flows over the Baudelot cooler into a well and from thence is drawn by the pumps and returned to the second stage.

TABLE II.—*Daily Report of Operations in Blowing Engine House, Day ending April 6th, 1912.*

Time.	Blowing Engine No. 1.				Blowing Engine No. 2.				
	Revs. order'd	Air temp.	Cor'ct revs	Revs. made	Revs. order'd	Air temp.	Cor'ct revs.	Steam press.	Air press.
6 a.m.	40	56	40	...	32	90	34	110	12
7 a.m.	40	60	40	40	32	87	34	110	11·5
8 a.m.	40	60	40	40	32	86	34	110	12
9 a.m.	40	65	41	40	32	90	34	110	8
10 a.m.	40	70	41	42·5	32	87	34	110	11·5
11 a.m.	40	73	42	40	32	91	34	110	12
12 m.	40	75	42	42	32	92	34	110	11·5
1 p.m.	40	75	42	40	32	93	34	110	11
2 p.m.	40	79	42	41·5	32	95	34	110	11·5
3 p.m.	40	75	42	42	32	96	34	110	11·5
4 p.m.	40	75	42	42	32	95	34	110	12
5 p.m.	40	74	42	42	32	95	34	110	12
6 p.m.	40	71	41	42	32	93	34	110	12
7 p.m.	40	67	41	39	32	88	34	110	12
8 p.m.	40	63	41	41	32	95	34	110	11
9 p.m.	40	62	42	41	32	95	34	110	11
10 p.m.	40	62	41	41	32	96·5	34	110	11
11 p.m.	40	61	41	41	32	96	34	110	11
12 night	40	61	41	41	32	94·5	34	110	8
1 a.m.	40	59	41	40	32	94·5	34	110	12
2 a.m.	40	60·5	41	41	32	95	34	110	12
3 a.m.	40	59·5	41	41	32	95	34	110	12
4 a.m.	40	59	41	41	32	95	34	110	12
5 a.m.	40	62	41	41	32	96·5	34	110	14

At the end of the second stage are located a thermometer well with mercury thermometer and the resistance bulb of an electric thermometer by which the temperature of the outgoing air is read at the desk in the dry blast room. In addition, a Bristol recorder, which is located at the desk, shows the outgoing air temperature at all times, as well as furnishing a record of each day's operations when taken in connection with the pressure chart.

As the moisture removed from the air in the second stage passes into the brine, it is necessary to remove, by boiling, an equal amount from the brine. This is accomplished by means of an evaporator using exhaust steam, the steam from the brine being condensed in a small jet condenser. The cold brine to the evaporator and the hot brine drawn from it pass through the interchanger.

In Table I. is given part of the record or log for the day ending April 1st, 1912. Particular attention is directed to

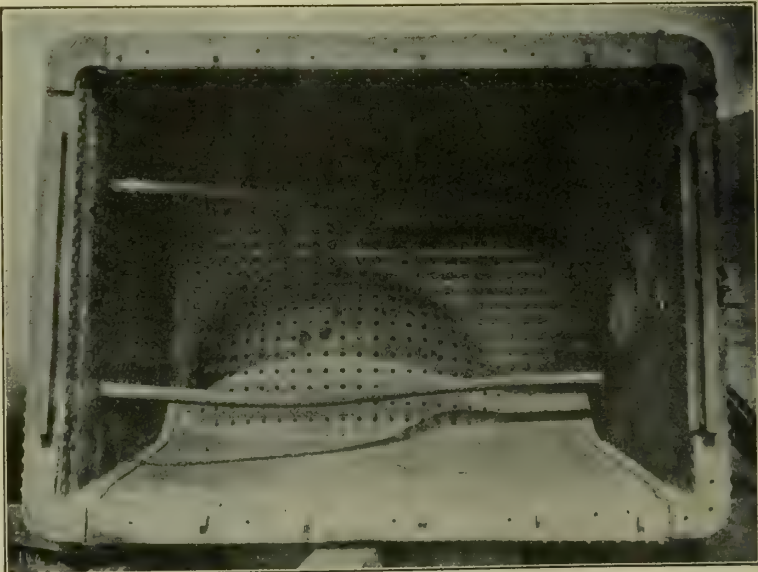


FIG 4.—INTERIOR OF RADIAL STAY FIREBOX AFTER LOW-WATER TEST. (See p. 79)

the readings of moisture taken from a connection on the bustle pipe and their close agreement with those taken in the dry blast room. The air sampled at the bustle pipe has been heated in the stoves to 1,100° or more, and cooled down by passing through a pipe coil to such a temperature as will

permit of dry and wet bulb readings. If any entrained moisture were carried with the air from the second stage, its presence would be detected in these readings. The close agreement of the readings with the moisture calculated from the



FIG. 5.—VIEW OF EXPLOSION OF LOCOMOTIVE BOILER FITTED WITH RADIAL STAY FIREBOX. (See page 79.)

temperature and pressure of the air leaving the second stage proves conclusively that the end eliminator removes practically all of the entrained moisture.

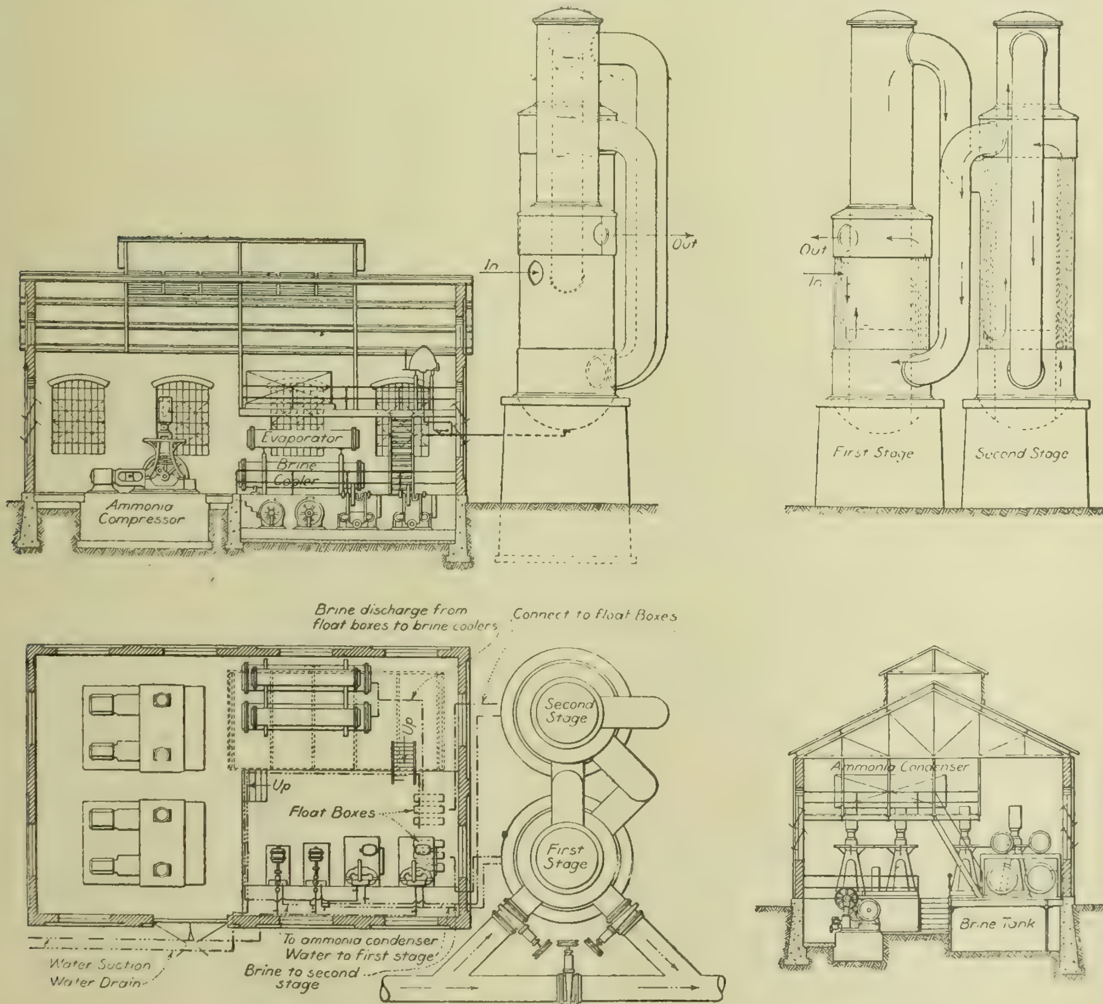
At present, on account of some improper action of a spring forming part of the mixing valve mechanism, the automatic controller, which will eventually regulate the temperature of the outgoing air, has not yet been put in use. The remarkable regularity of the moisture readings shows the ease with which the necessary regulation is accomplished by means of hand control of the two pumps.

Table II. is a sample engine room record, and illustrates the method of obtaining regularity in the quantity of air in pounds delivered to the furnace, the speed of each engine being changed each hour if the change in the temperature of the air entering the blowing cylinders requires it. By means of the electric thermometer, the temperature of the air entering the blowing cylinders is read hourly in the dry blast house, and the necessary correction made from a chart. The revolutions ordered by the furnace manager are assumed to be based on an arbitrary temperature of 50°, and the engines are run faster or slower, as the air is warmer or colder, than the standard.

It is not found necessary to change the speed frequently during the 24-hour period. Engine No. 1 takes its air from outside through a pipe, and in consequence its speed must be changed more frequently than engine No. 2, whose air is of more constant temperature as it comes from the engine room. As the dry blast apparatus is operated by one man on each turn without difficulty, the operating expense should compare very favourably with that of any other process.

The accompanying illustrations show the arrangement for a 40,000-cub. ft. plant and attention is directed to the small amount of refrigerating apparatus required. The coolers are in the shape of towers, and each cooler is surrounded by an annular space in which the tubes of an interchanger are installed. These interchangers not only reduce the amount of cooling to be done in the first and second stages, but in addition, heat the air before it reaches the cold blast main to a degree as high or higher than would be the case if the air had been treated in the older process of cooling before compression.

As the initial cost as well as the operating expense of a plant using this process is much lower than that of any possible arrangement of apparatus using cooling before compression, and only a fraction of that of the original type using pipes for cooling, it is believed that its introduction will result in a great extension of the use of dry blast.



PLAN AND ELEVATION OF DRY BLAST APPARATUS FOR HANDLING 40,000 CUBIC FEET OF AIR.

THE CORE ROOM: ITS EQUIPMENT AND MANAGEMENT.*

BY HENRY M. LANE.

(*Concluded from page 49.*)

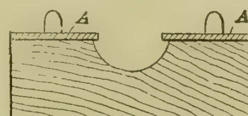
Self-pasting Cores.—Many intricate cores must be made in halves and then either dried on flat plates and pasted, or the two halves rocked together before pasting. If the latter is done, the binder must be of such a nature that it will form a self-pasting core. High-grade core oils when used in fairly large proportions will generally bind the two halves together in cases of this kind. In some cases, however, the expedient shown in Fig. 3 must be resorted to. One-half of the box is provided with a thin metal sheet shown at A which projects slightly over the edge of the box. After the two half-cores are made in the boxes the metal plate A is lifted off and the two halves of the box closed together. When the halves first meet, the condition will be as represented in the lower portion of Fig. 3. As the box is closed together, the projections of sand left by the opening in the plate A will crush into the faces of each half of the core so as to bond thoroughly the sand in the two parts. This device, the writer believes, was patented some years ago by Mr. Lee, superintendent of a department of the Crane Company. In other cases the coremaker is careful to leave the sand projecting slightly above the face of the box when he strikes it off, and then when the boxes are closed together there is sufficient pressure to make the sand along the faces of the core adhere. These rock-over boxes are now used in a number of different classes of work either with or without the stripping device, and their use simplifies the making of intricate cores and at the same time permits the drying of the entire core in one piece. Where cores are made in halves, as shown in Fig. 3, and then rocked together, some form of block is generally employed for pressing a vent into the face of one-half of the core. The introduction of this vent block swells the sand on both sides of the vent, and this is usually sufficient to make the core self-pasting.

Grinding Experiments.—Concerning the compounding of core mixtures, the writer has tried a great many experiments, and was aware that the grinding of moulding sands greatly increased their strength, and under the impression that a similar grinding would aid core sands. In this connection a series of tests were made. A Wadsworth mixing and compounding mill was used, having a pair of small rollers running around on an annular track, following which are scrapers that turn the sand over first one way and then the other. A number of different classes of mixtures were put through the mill. In the case of sharp sands mixed with oil, grinding in the mill from 1 min. to 2 mins. was found to be a decided advantage over hand-mixing. After 5 mins., however, there was a marked falling off of the strength of the core, due evidently to grinding the sand in such a way as to form dust, which absorbed the oil and prevented its acting as a binder between the sand grains. One of the mixtures tested consisted of 120 parts of Lake sand, 60 parts of Del Ray bank sand, 5 parts by volume of No. 1 Peterson's core oil, and 1 part by volume of flour. Cores made from this mixture showed a strength of over 60lbs. per square inch after a grinding of 2 mins. A large batch was made up, thoroughly mixed with the shovel, and then succeeding parts of it put through the mill, grinding the first 2 mins., the second 5 mins., then 15 mins., 20 mins., and 30 mins. Several series of this kind were run, and in each case the initial strength of the material was about 60lbs. per square inch, while the final strength ground 30 mins. averaged less than 30lbs. per square inch.

An experiment was then made by grinding a facing-sand mixture for dry sand moulds. This was composed of four parts of new Zanesville moulding sand, 52 parts of heap sand, ¼ part of glutrin, and ½ part of dextrine. With this the strength increased slightly for the first 10 mins.' grinding, and then remained constant for grinding up to 30 mins. In it there is no bond that would be injured by fine material, as in the case of the oil-sand cores already described. It is evident, therefore, that in the case of oil-sand cores all that is required is a thorough mixing or blending of the ingredients. The hand-mixing experiments tried at the same time showed conclusively that if the oil and water were not ground together in contact with the sand so as to form an emulsion and to bring it in contact with the grains, the core would have unbonded spots. The writer has also had access to the records of several foundries using mixing and compounding mills of various types, and found that in all cases the oil-sand mixtures require thorough blending, but are the better for not being ground with heavy rollers. Loam-sand mixtures require more grinding, and in this respect are similar to moulding sand.

The selection of core materials will probably remain for some time in the hands of the core-room foreman, but the writer confidently expects to see all of the larger concerns and the more progressive foundries placing the control of these supplies in the hands of the laboratory, just as they have placed the control of their metals and fuels in the hands of the laboratory.

Core Ovens and Core Drying.—The baking or drying of a core is a complex process, depending upon the character of the sands and the nature of the binders used. Where flour, starch, or dextrine are used, the moisture is first driven out and then the starch or flour compound is baked, as in any ordinary bread-baking process. To develop the greatest strength the material must not be charred, but should be carried simply to the condition of ordinary bread crust. For this purpose the temperature should be between 350° and 375°, and under no circumstances should it be allowed to rise above 400° to 410°. If flour or starch bonds are charred they immediately lose strength. Such a core taken from the oven at its condition of maximum strength will still contain some moisture in the starch or flour compounds, this moisture being mechanically combined, and naturally gives off a great deal of smoke when the mould is poured.



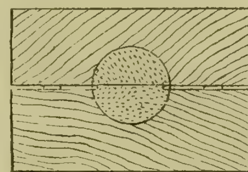


FIG. 3.

In the baking of resin or pitch cores it is necessary only to heat the material to such a temperature as to cause the resin or pitch to flow and unite the grains of sand. Practically all black core compounds contain a considerable percentage of dextrine, and on this account the baking partakes both of the nature of the process already described and of the melting of the pitch, causing it to flow through the sand. This requires only a temperature of 350° to 400°, and if heated much above 410° the dextrine contained in the black compounds will be burned out or, in the case of the resin core, some of the resin oils will be distilled off and the material will lose in binding power. Most of the resin oil, however, does not distill off below 550°, but at 640° Fah. over 90 per cent. of it can be driven off.

In both of these classes of cores described, the first operation is to drive out the water, and the second simply a baking or melting, as the case may be. In both cases, during the first part the core oven should have ample ventilation so as to drive out the steam as it is formed. During the latter part a free circulation of air is not needed, and in fact not desirable, as it would tend to oxidise or burn the compounds forming the bonds if the temperature of the oven got a little too high.

With oil-sand cores an entirely different proposition is encountered. The active bonds are the drying oils with the exception of resin, which is sometimes blended with the core oil. The drying or paint oils all require a good circulation of air through the oven. As in the previous cases, the first action which takes place is the driving out of the moisture contained in the core, and the second largely the oxidation of the oil. If a blended or compounded oil is being used which contains mineral or tar oil, or any similar compound, there will be some volatile hydrocarbons which will be driven out. After this it is necessary to continue a good circulation of air through the oven to oxidise the oils.

The process going on in the core oven during the latter part of the drying of an oil-sand core is similar to that of drying oil-skin clothing. This clothing is made by dipping

* Abstract of paper read before the American Society of Mechanical Engineers.

cloth in a mixture of oils and drying it in a current of warm air. If the rooms containing the clothing to be dried are shut up so that there is no current of air, the oil will remain moist for days, even though the temperature may be much above that ordinarily employed for the purpose. With a good circulation of air, however, the clothing will dry rapidly to a firm, hard skin. In like manner oil-sand cores must be given plenty of oxygen if they are to be properly dried.

Very few of the bonding oils will be burned at temperatures below 500°, and hence when they are being used core ovens can be driven at a higher temperature than with flour or starch. There is no need, however, of carrying the temperature above 400° to 410°, and the writer believes that the best results are obtained at about this range. If the temperatures reach 600°, all forms of carbon used in core binders begin to char and the strength of any carbon bond is reduced. The cores already spoken of, composed of silica sand, Welsh mountain clay, and sawdust, were baked at about 600°, for the purpose of charring the last ingredient. With ordinary binders, however, this would not be a proper procedure.

As a rule a foundryman keeps no record as to the part of his oven in which certain cores were baked, and may be wholly unaware of the fact that from 10 to 30 per cent. of the product is seriously damaged every day, and that in many cases castings are lost on account of being baked at too high a temperature in hot parts or not thoroughly baked by being left in cold parts.

If all core ovens were equipped with recording thermometers and account taken of the time different cores were placed in the oven, the foundryman would have a record of the baking temperature of each batch of cores, and would thus be able to trace irregularities in the quality of the cores to the baking temperatures, if variations in these temperatures were to blame. When workmen know that a recording instrument is watching them and drawing a record of just how they maintain the temperature in the oven, they will look after the fire and the draughts and see that the record is a credit to them. The writer believes it is a good thing to put the recording thermometers where the foreman can see them, and then hold him responsible for the results, for many castings are ruined through bad cores and the trouble laid at the moulder's door or considered a mysterious dispensation of Providence.

Core-Oven Design. — It is not intended in this paper to go into an exhaustive discussion of core-oven construction, but the underlying principles of core-oven design will be stated. If it is to be efficient it must be so constructed as to maintain a practically uniform temperature throughout the entire drying chamber. For the best results the extreme variations between different parts of this chamber should not exceed 60° Fah. There also should be a proper circulation through the oven to insure the carrying off of any steam generated during the first period of drying of cores and to afford an ample amount of oxygen for oxidising and drying oil binders. Where no oil binders are used and the cores are dried in batches it is advisable to vary the amount of circulation through the oven at different periods of the drying process so as to avoid undue oxidation of certain classes of binders toward the end of the drying period.

The most common mistake made in core-oven design is that of locating the firebox too close to the oven and of discharging the products of combustion into the core-drying chamber at too high a temperature. This practice renders certain portions of the oven inoperative for efficient baking on account of the fact that if any cores were located in these hot parts they would be burned. In the oven there should be ample space between the combustion chamber, or firebox, and the oven, or drying chamber, for the mixing of the products of combustion, so that they will have a uniform temperature when entering the oven, and this should be the maximum baking temperature of the oven. The most efficient ovens that have come under my attention have all had their firebox located at some distance from the oven proper, or else have had a large mixing chamber introduced in the flue between the oven and the firebox. In one case there is a battery of ovens constructed with fireboxes in the basement and the ovens are located two storeys above. The flues are so arranged and provided with dampers as to make it possible to control the temperature and volume of the incoming gases entering each oven or oven compartment. A provision of this kind insures rapid drying without any danger of burning the cores.

Steam-heated Core Ovens. — For some classes of binders steam-heated ovens are excellent, since they insure control of the temperature and preclude any possibility of its rising above the desired maximum. The fuel economy of the steam-heated oven, however, is very low, and hence some form of direct firing by carbonaceous fuel is generally depended upon.

Core-Oven Fuels.—The fuel used must be one that does not give a smoky flame which would cover the cores with soot. In consequence, anthracite coal, coke, fuel oil, and gas, are the fuels commonly employed. The products of combustion from anthracite, coal, and coke are carbon dioxide, with possibly a little carbon monoxide if there is imperfect combustion. With these are mingled a large amount of nitrogen, which is passed through the oven with the air supply to provide oxygen for the combustion of the solid carbon. All of these gaseous products are efficient drying agents, and have the power of absorbing moisture and carrying it from the core oven with them.

Turning to fuel oil or gas as a means of heating the oven, an entirely different set of fuels is encountered. Both of these fuels contain larger percentages of hydro-carbons, all of which burns to water, which passes off as steam, and as its temperature falls in the core oven it tends to saturate the air with steam, and hence is not efficient as a means of carrying moisture from the oven. In other words, while all of the combustible material in oil or gas produces heat when it is first burned, the products of combustion are of such a nature that much of the heat is carried through the oven locked up in the steam resulting from the burning of the hydro-carbon compounds, and so is not available for the drying of cores. The exceedingly high thermal efficiency of gas and oil, however, and the fact that the use of fuels of this kind does away with the handling of coal or ash may make it advisable to use such material though it is not the most efficient fuel.

Continuous Core Ovens.—In the case of continuous ovens, where the cores are carried by mechanical means, care should be taken to see that there is no hot spot in the ovens where the temperature exceeds the safe drying limit for the binder in use. Cores may be made to resist high temperatures by spraying the surface of the cores to increase the percentage of binder in the surface, but this is expensive since in spraying cores much of the material is wasted, and the operation itself takes time. It is far more economical to design the oven so that it will bake the cores with the maximum degree of rapidity and at the proper temperature, than to try to utilise improperly designed ovens by doctoring the core-room practice. One advantage of continuous ovens over many of the other types is that the temperatures of the different parts may be controlled so as to give the most rapid and efficient drying possible, but this is true only where the cores are approximately uniform.

Chamber Ovens with Shelves. —For chamber ovens in continuous use, the cores being dried on individual shelves, it is necessary to determine the condition of the drying by inspecting the cores. In such ovens the products of combustion usually rise and pass out of the top, and if there are partially baked cores on the upper shelves and subsequently green cores beneath them, the steam driven out of the green cores passes over the dry cores and the moisture may, to some extent, be absorbed by the dry cores, thus retarding their baking. In any case the presence of steam in the ascending current of air will retard the baking on the upper shelf. This is one reason why the lower shelves of a drying oven frequently bake faster than the upper shelves, even when the temperature of the incoming gases is kept well below the maximum allowable for the oven.

Distortion of Metal Parts of Core Ovens.—Core ovens have been arranged in many cases so that the fire was 1ft. to 3ft. from the cores being dried. The core cars have often been warped and bent out of shape by the fact that the flame from the fireboxes played against them. Iron will not be distorted at any temperature that is safe for the baking of cores, hence any warping of any metal work in the oven is

evidence of too high temperature. For the proper regulation of the temperatures in core ovens, recording thermometers should be applied not only to the ovens themselves but to the main heat flues.

Core-Oven Cars. — For efficient core-oven work the car must be designed so that it will support the cores without any danger of being distorted. The tracks for supporting the car must also be rigidly supported and kept in perfect condition. Too little attention is given to the design of this part of the core-room rigging. The core trucks or cars should run into the oven as easily as any other part of the industrial transportation system.

Core Pasting, Handling, and Storage. —With the increasing demands from the designing department for greater accuracy in finished castings, it has been necessary to improve the core-room rigging to ensure the accurate fit and location of the cores. For convenience many cores are made in halves, so that they can be dried on flat plates. This method also affords an opportunity for the forming of vent passages on the parting. After baking they must be assembled and pasted together.

Drying Pasted Cores. — After the cores are pasted it is necessary to dry the paste before introducing the cores into the moulds. In some cases a torch is used to dry the paste near the edges of the parting, and the cores sent directly to the mould, but the maximum adhesion of the paste has not been developed and the core is likely to shift. Generally a regular core oven is used for drying, the pasted cores being placed on plates and introduced on to core-oven cars or placed in drawer ovens.

Core-Testing Gauges. — After the cores have been dried they are tested by means of various gauges. It is no uncommon thing for the modern foundryman to hold his core work within limits of a few thousandths of an inch for medium-sized cores and within 0·01in. for cores 1ft. or more in diameter or length.

It is also possible to use setting jigs for placing cores in the mould to ensure the proper fit of the various parts.

Handling the Dry Cores. —The handling of cores is of importance. Every time a core must be picked up and set down there is danger of its being broken and an expense for the labour involved. Cores should pass from the oven to the moulder with the fewest handlings consistent with the maintenance of a sufficient stock of cores to ensure continuous work in the foundry and also with distribution of the work in the core room so as to allow the coremakers to complete batches of a given style of cores in the most efficient manner.

Where the operations are such that a constant number of standard cores are required they should be taken from the core-oven trucks, and placed directly on some form of carrier which will deliver them to the moulders. In the case of small chunky cores, such as are used in fitting shops, the cores are often piled into boxes, and these in turn laid on the trucks or on racks supported from overhead trolleys and then transported to the moulders. Where cores must be passed to a storage or must be pasted subsequently to drying, they can be taken from the core-oven trucks, laid on industrial railway cars and delivered to the storage or pasting departments and to the foundry as required.

Handling Green Cores. — Where possible the coremaker should place the plate carrying the green cores either on the shelves of the core-oven truck in which it is to be dried or on a conveyer, which will carry the cores to the core oven. For medium-sized plants one of the most efficient methods is to have the core-oven trucks so designed that they will run on tracks between the coremakers' benches. The coremakers place the cores on the shelves of the truck and labourers then run it out from between the benches to a transfer car which delivers it to the oven in which the cores are to be baked. After the cores are dried the truck carrying the dry cores may be taken to the core storage, or the dry cores may be placed on industrial railway trucks or carriages supported from a trolley system and carried either to the storage or the foundry.

Protecting Cores from Dampness. — Complaints are constantly made to the effect that flour, starch, dextrine, or glutrin cores become soft if left in storage. The reason for this is that if exposed to moisture-ladened air these cores will absorb moisture. The author has seen a core storage located in a cold unheated building, with the exhaust from an engine playing past the unclosed windows so that the exhaust steam came in over the cores in clouds. They might just as well have played water from a hose over them so far as the effect was concerned.

On the other hand, there are a good many heated core storages. In most cases these are located over the core ovens and take advantage of the waste heat from the core ovens. In other cases they are located over malleable annealing ovens or in any place where there is waste heat available. In some other cases they are heated with steam coils or stoves fired with coke or natural gas. The author has seen flour cores taken from such a heated storage and used after they had been in storage for three years, and they were just as good as the day they were made. Glutrin cores made with gangway sand have been used after they were many months old. In many plants it is the practice to leave cores standing upon the moulders' floor from one to three days before they are used, or to introduce them into moulds long before they are used.

Moisture in Moulding Sand. — In order to ascertain the moisture conditions that the core must meet in the mould, samples of the moulding sand were taken from many foundries in different parts of the country and moisture determinations made. The amount of moisture used in moulding sand was found to vary from less than 5 per cent to over 10 per cent., and in the same foundry it will frequently vary 3 per cent. in a single day. By watching the moulding operations the author has been able to predict which moulds would be lost before they were poured, and these predictions were verified when a badly blown casting was shaken out. In one case the foundryman had been blaming first the iron and then the coremaker; it was proved conclusively that the trouble lay in the too free use of the swab on certain moulds. A core made from any of the standard binders should be able to remain in the mould from morning until afternoon without any danger of its absorbing an excessive amount of moisture, providing the core has not been subjected to undue moisture in the storage or the moulding sand has not been worked too wet or over-swabbed.

Location of Core Storage.— The core storage in any plant should be so designed and located that the cores can be handled with the least amount of labour, and also so that the number of cores of any given kind on hand may be ascertained readily at any time. The placing of the core storage on the second floor usually makes it possible to utilise some waste heat for the protection of the cores, and the transportation of the cores to and from the storage by elevator adds but little to the expense, as vertical transportation is very cheap.

Types of Core Machines.— Core machines in so far as they affect core sands and core-binding materials are considered in this paper. There are four distinct types of core machines in general use. The best known and probably the oldest type is that which corresponds to the hand-rammed moulding machine. In this case the core boxes are simply attached to a moulding machine, the core sand rammed in the boxes, and the machine used for rolling over and drawing the boxes away from the finished core.

Another type of machine which has long been in use is the screw-feed machine forming a core through a die. The plunger-feed machine works on the same principle so far as the die is concerned. In a machine of this kind the core mixtures must be forced through a die and on to a plate. Such a mixture must contain sufficient green binder to make the core stand up on the plate and sufficient oil to make it slip on the plate without being torn up. These conditions are antagonistic, as the green binder depended upon is usually flour and the core oil neutralises much of the effect of the flour. Core mixtures for use in machines in which the core is forced through a die must contain an excess of binder, but the capacity of the machines is usually sufficient to more than pay for the excess of binder used. Such cores usually vent fairly freely in spite of the excessive amount of binder, and the reason for this is that the large amount of flour used shrinks greatly during drying, thus giving added vent space.

Where silica sand or a good sharp sand is used as a base with a proper binder the cores will neither shrink nor swell appreciably during baking, and, in fact, George H. Wadsworth has succeeded in producing both square and round cores which were kept within limits of 0·004in. over or under a given size. This is a total allowable variation of less than 0·01in. Machines of this type, that is, either the screw-feed or plunger-feed machine, are extensively used for forming parallel-sided stock cores.

For forming irregular cores a new type of machine has come on the market within the last few years. This is known as the Hulet machine. In this the core mixture is blown into the core box by compressed air and the packing accomplished by the impact of the sand as it enters.

The jar-ramming moulding machine was very promptly applied to core making, and a large variety of special jar-ramming machines have been developed for this purpose. Jar-rammed cores vent more freely than hand-rammed cores on account of the fact that hand ramming tends to form hard faces, which effectually block the flow of the gases through the mould, and so interfere with the vent. In the case of automobile cylinder jacket cores and other intricate work made from silica sand and oil mixtures, jar ramming has almost eliminated the use of artificial vents.

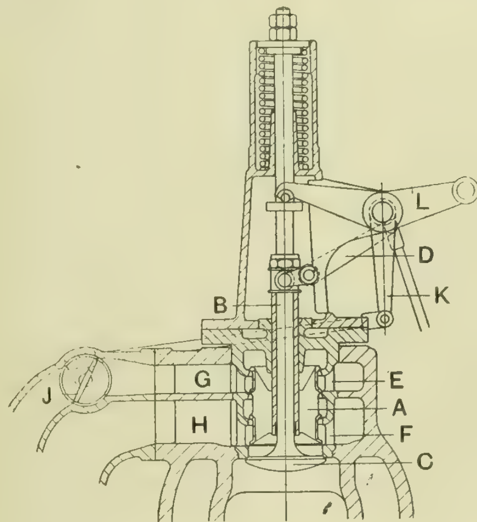
In the case of large cores made from pitch or black compound mixtures or from any mixtures suitable for heavy work the jar-ramming machine can be used with special or ordinary standard boxes. A layer of facing sand is first shovelled in, next the core box, the core arbors, and the core bars are introduced together with any coke or other material that may be required to form vent passages, the remainder of the sand is then introduced, and the whole mass jar-rammed, the core arbors and core bars settling down into the sand as it is rammed. This results in a uniformly rammed core, which does not have a tendency to swell and become irregular in drying, as is often the case with hand-rammed cores. Such a core also vents more freey than a hand-rammed core.

These advantages alone would be sufficient to induce foundrymen to introduce core machines into their foundries, but there is the additional advantage of larger output, and the author is convinced that in the future there will be an increasing use of machines for forming cores in the foundry. In addition to the types of machine already specially referred to, nearly every type of moulding machine has found its application in the making of some kind of special cores. The roll-over moulding machine is being used extensively for the production of automobile jacket cores.

Sand - Handling Equipment. — Particular attention should be given to the storage, preparation, and mixing of core sands. The sand should be put into storage at the time of year when it is driest, as this saves freight, and also ensures sand in better condition for core work. Core sand should always be kept under shelter. The method of storing sand will depend largely upon the size of the plant. For comparatively small plants a series of covered bins may be arranged in the basement, and the sand introduced into them through chutes in the side of the building from a switch outside or dumped into them through hatches in the roof. For the storage of large quantities of sand, concrete bins are best. The sand is handled into the bins and from there to the foundry by means of a grab bucket operated by means of a crane. For smaller plants some conveyer system is advantageous, the sand being conveyed from the bins to the mixing machinery by means of a belt conveyer. Where the cores are made by hand the core sand can be delivered to the operators' benches either by means of boxes carried on trucks or supported from overhead trolleys, or by a conveyer system, but in most cases the latter is more complicated, and for this reason not desirable. Another objection to it is that in most plants several core mixtures are in use, and in some cases the same operator may work on different mixtures during different parts of the day. For moderate-sized plants working only from four to ten bench coremakers, a mill of the Wadsworth type, that is, a small mixing and compounding mill with small rollers, gives excellent results. The experiments tried in the mixing of sands at different foundries indicate that for all sharp sand mixtures the sands should be thoroughly mixed but not ground, and for this reason a paddle mixer working on the principle of the ordinary pug mill used in brick manufacture is suitable.

VALVE GEAR FOR INTERNAL-COMBUSTION ENGINES.

THE accompanying illustration shows an arrangement, patented by Mr. A. G. Haffenden, and Messrs. Kynoch, Ltd., of Lion Works, Witton, Birmingham, for controlling the mixture of gas and air, or the gas only of an internal-combustion engine by means of an equilibrium throttle valve sliding on the spindle of the main inlet valve, and arranged concentrically with, but quite independent of it. A is the equilibrium throttle valve sliding on the main inlet valve spindle B. This valve is placed as near as possible to the main inlet valve C, so that there is a minimum of space for the accumulation of mixture, thus making the engine respond more promptly to the action of the governor and also preventing back fires. The valve is raised or lowered by mechanism attached to the governor, such as the lever D, so as to reduce or increase the size of the gas and air ports E and F, according to the load on the engine. By throttling the gas and air by means of this separate equilibrium valve the governor is free to work during any portion of the inlet stroke,



VALVE GEAR FOR INTERNAL-COMBUSTION ENGINES.

thus rendering this gear especially suitable for multicylinder engines. The valve as shown is an equilibrium valve of the lift type which is neither a piston or slide valve, in which the outside circumference of the throttling edges never come in contact with the surface of the ports during the normal working of the engine. As a consequence of the valve A being usually partly or altogether open, the gas and air passages G and H may communicate with each other, and as this is undesirable except when the main inlet valve C is open and a mixture is being drawn into the cylinder, another valve J is placed in the gas passage G, which is opened each suction stroke by mechanism such as the lever K, attached to the main inlet valve lever L, or by an auxiliary cam. This auxiliary valve is arranged to close a little before the main inlet valve, thus interrupting the stream of gas and ensuring the passages being swept out by pure air.

Boiler Explosion at Wishaw, near Glasgow.—A disastrous boiler explosion took place at 9 a.m. on the 10th inst., at Allanton Foundry, Morningside, near Wishaw, belonging to Belhaven, Ltd., Wishaw, resulting in considerable damage to property, the death of three workmen, and serious injury to other three. By the force of the explosion the windows of the pattern shop, back and front, were completely shattered, and three of the workers in this shop, who were in line of the escaping steam and the flying débris, were severely scalded and bruised. The large entrance doors of the moulding shop were also blown down, and two workers who were in that vicinity also suffered injury. It is stated that the day of the explosion was the last day on which the boiler was to be in use, arrangements having been made to replace it by a new boiler, and that the owners, Messrs. Belhaven, Ltd., formerly Belhaven Engineering and Motors, Ltd., took over the works only a day or two before the disaster.

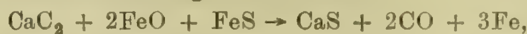
THE MANUFACTURE OF ELECTRIC STEEL.

THE usual process followed in the manufacture of steels in an electric arc melting furnace is, in the case of the steel being entirely produced in the electric furnace from cold scrap or raw material, to oxidise out the phosphorus, manganese, silicon, and carbon to whatever extent is desired by addition of iron oxide to the bath or slag. When this oxidation has proceeded sufficiently, the slag is raked off the metal, and, if desired, a second and a third similar slag washing is given. When the metal is judged to be sufficiently free from some or all of the above elements a final slag consisting usually of lime, sand, and fluor-spar, or lime, fluor-spar, and a substance, such as bauxite, containing alumina and silica, is thrown on the metal and some carbon spread on the top. A function of this slag is to deoxidise the bath and to reduce the sulphur content of the steel. The reaction within the slag, after the iron oxide is reduced therein, is probably the following : —



$$CaO + 3C \rightarrow CaC_2 + CO,$$

and that between the slag and the bath :



$$CaC_2 + 2FeO + FeS \rightarrow CaS + 2CO + 3Fe,$$

the FeO and FeS representing the probable state of the oxygen and sulphur in the metal.

Another reaction which takes place within the slag, when the latter is free from iron oxide, is represented by



$$SiO_2 + 2C \rightarrow Si + 2CO;$$

the silicon entering the metal below. This reaction makes it impossible to obtain a steel with only a trace of silicon by hitherto known means in the electric furnace, whereas steels which are required of exceptional ductility should contain the least possible quantity of this element. In a recent patent granted to Mr. Victor Stobie, of the Stobie Steel Company, Warren Street, Sheffield, two methods of producing electric steel are described in which only traces of silicon are found. In addition to reducing silicon from the silica in the slag, finishing electric steels by the usual method is expensive by reason of the consumption of electricity during such time as is occupied by the reactions, which take from half an hour to two hours, according to the state and nature of the steel. Of the two methods, the first is preferably followed if desulphurising by the finishing slag is not required, and the second preferably when desulphurising and deoxidising are both required.

In the first method any usual finishing slag may be placed in the bath, but preferably one composed of about 60 per cent. to 70 per cent. lime and 30 per cent. to 40 per cent. fluor-spar. Sufficient carbon is thrown on this slag when fluid to free it from any oxide of iron held by it. The quantity necessary will vary with the iron oxide held by the slag, which, in turn, will vary with the oxidised state of the bath, the time the slag has been thereon, and the heat of the furnace. The desideratum is to quite free the slag from iron oxide whilst maintaining the slag as fluid as possible by having little excess of carbon or other slag deoxidant. When the slag has thus been freed from iron oxide, aluminium is introduced into the metal. The quantity of aluminium will depend upon the oxidised state of the steel; samples taken from the bath in the usual way will indicate when the metal is ready for tapping.

The second method is similar to the above except that an ordinary finishing slag, composed of, say, 60 per cent. lime, 15 per cent. each sand and spar, and 10 per cent. carbon, is allowed to desulphurise in the usual way for some time, during which some deoxidation will also proceed; the process being completed as by the first method as soon as desulphurising is sufficiently effected. By this method some small quantity of silicon will, however, enter the bath. The steel must be kept in the furnace a minute or two after deoxidation, when only most minute traces of aluminium will be found in the metal. The minute or two rest gives the alumina produced sufficient time to slag out of the bath. Aluminium estimates on steels thus produced have shown ·00 per cent. to ·01 per cent. aluminium. By the use of aluminium as above the time required for finishing steel in an electric furnace will be curtailed by 20 per cent. to 80 per cent.

INDUSTRIAL AND TRADE NOTES.

Stockport's New Reservoir.—The new reservoir at Kinder, which will furnish the water supply for Stockport and neighbouring townships, was formally opened on the 11th inst. It covers 44 acres, and holds 515 million gallons. It has the largest earth dam in the world.

Re-starting of the Solway Ironworks.—The Solway Ironworks, Maryport, owned by the Workington Iron Company, re-started on the 12th inst., after being idle since last August. They employ about 250 hands. It is understood that the dearness and scarcity of coke since the railway strike kept the works from re-starting sooner.

Big Bridge Contract for India.—The contract for a new bridge, consisting of no fewer than 15 deck spans, each of 90ft. length, required for carrying the broad gauge railway over the River Ravi —one of the five great affluents of the Indus—at Lahore, has been placed by the India Office with Messrs. Head, Wrightson, and Co., Ltd., of Thornaby-on-Tees.

Important Ironworks to be Re-started.—We understand that the Osier Bed Ironworks at Wolverhampton, the property for many years of Messrs. John Lysaght, Ltd., the steel and galvanised iron making firm, are to be re-started, after having been idle for several years. The site has been purchased by a new company who are about to lay down 16 puddling furnaces, and a number of mills for bar iron and strip manufacture. Steel manufacture may also be added later.

Oil-propelled Tank Boat.—There was recently launched from the yard of the Reiherstieg Schiffswerke und Maschinenfabrik at Hamburg a new tank vessel of 7,500 tons capacity, which has been constructed for the Deutsche Petroleum Gesellschaft. The boat is fitted with Diesel oil motors of the 6-cylinder 2-cycle Carels type. The bunkers have a capacity of 600 tons, sufficient for a voyage of 50 days. She will carry a crew of 11 men, as against 18 required in a steamship of the same power and size.

German Pig-iron Output.—The production of pig iron in Germany during the month of June amounted to 1,418,445 tons, or 45,165 tons less than in May, but still materially larger than in any month prior to March of this year. During the past half-year Germany produced 8,426,266 tons, against 7,682,555 tons last year, 7,202,032 tons in the same period of 1910, and 6,249,589 tons in 1909. The increase of the half-year is thus nearly 10 per cent. compared with 1911, 17 per cent. compared with 1910, and 35 per cent. compared with 1909.

The United States Metallic Packing Company, Ltd.—Some 12 months ago this company acquired a site of about 2½ acres at Allerton Road, on the outskirts of the city of Bradford, and erected thereon large and convenient premises, specially adapted for the manufacture of metallic packings, steam traps, &c., and fully equipped with most suitable appliances. The business has now been transferred from the old premises, and the new works and offices are in full swing. The additional space provided will enable the company to cope more efficiently with their increasing trade. The new address is the United States Metallic Packing Company, Ltd., Soho Works, Allerton Road, Bradford.

Shipbuilding Records.—The returns compiled by Lloyd's Register of Shipping for the second quarter of the year show that, excluding warships, there were 529 vessels, of 1,774,040 tons, under construction in the United Kingdom at the end of June. For the first quarter the figures were 545 vessels, of 1,686,898 tons, so that the work in hand has increased during the three months by about 87,000 tons. The figures for the period under review are the highest ever recorded in the society's quarterly returns, being 298,000 tons in excess of the tonnage which was in course of construction at the end of June, 1911. The figures for the warship tonnage also constitute a record, the total number of vessels building being 67, of 503,003 tons. The previous highest total was that of 454,110 tons, which was attained in March, 1900. Of the 67 warships, 13, of 122,240 tons, are being constructed at royal dockyards, and 54, of 380,763 tons, at private yards.

State of Skilled Labour Market.—The monthly report prepared by the Board of Trade on the state of the labour market says that employment in June continued good, and showed, on the whole, some improvement on the previous month and a year ago. The weekly increase in wages during June was larger than the total weekly increase in the previous five months. In the iron and steel, tinplate, and engineering trades employment was very good. The ship-repairing industry in London was much affected by the dock strike. In the 390 trade unions, with a net membership of 833,940, making returns, 20,698 (or 2·5 per cent.) were returned as unemployed at the end of June, 1912, compared with 2·7 per cent. at the end of May, 1912, and 3·0 per cent. at the end of June, 1911. The changes in rates of wages reported for June were all increases, and amounted to £19,900 per week on the wages of 191,000 workpeople.

Iron and Steel Production in America.—Figures compiled by the American Iron and Steel Association show that the production of iron and steel in the United States during 1911 was far below that of 1910, and that last year was a period of reaction in the production of all leading iron and steel and auxiliary products. The production of pig iron in 1911 declined by 3,654,020 tons as compared with 1910; all kinds of steel by 2,418,813 tons, and all kinds of rails, 813,241 tons. The output of railroad cars by the principal car-building companies of the United States and Canada in 1911 decreased by over 58 per cent., and the output of locomotives by the locomotive builders in the two countries by over 25 per cent. The prospects of pig iron production in the United States for the current year are much brighter, and it is estimated that the figures are likely to be not far short of 29,000,000 gross tons. Up to the present the largest total for a calendar year was 27,303,567 tons, which was the output for 1910.

Mining in Scotland.—The report of Mr. W. Walker, H.M. Inspector of Mines for Scotland, states that during 1911 the total number of persons employed in and about the mines in Scotland under the Coal Mines Acts was 138,377, being an increase of 504 as compared with 1910. The total number of mines at work during the year was 518, as against 509 in 1910. The total output for the year was 46,548,384 tons, as compared with 46,205,552 tons in 1910, or an increase of 342,832 tons. The output of coal was 41,718,163 tons, or an increase of 383,031 tons. During the year 186 separate fatal accidents occurred in and about the mines classed under the Coal Mines Regulation Acts, causing 194 deaths, a decrease of nine in the number of accidents and of 15 in the number of lives lost as compared with 1910. The average quantity of mineral raised per person below and above ground is 336 tons, or 1 ton per person more than in the previous year. There was a large increase both in the number of coal-cutting machines at work and the quantity of mineral obtained by them, as compared with the previous year. The increase in the number of machines is no less than 95, and of the quantity of mineral obtained by them 1,097,191 tons.

Midland Ironworkers' Wages.—The demand of the puddlers employed by the firms associated with the Midland Iron and Steel Wages Board for increased wages and a limitation of working hours came before the Board at a meeting at Birmingham on Monday last. The Midland Wages Board covers not only the counties of Staffordshire, Shropshire, and Worcestershire, but many employers in Yorkshire, Lancashire, and South Wales are also affiliated. Puddlers' wages are governed by a sliding scale based on the net average selling price of all classes of iron made by 17 representative firms. The books of these manufacturers are examined every two months by a firm of accountants, and the ascertainment of production and selling prices is reported to the Wages Board. At the beginning of June the Ironworkers' Association held a meeting at Wednesbury, when it was decided to give notice to terminate the sliding scale. Since then there have been several informal conferences of employers. The meeting on Monday occupied two hours, and, as was generally anticipated, an amicable arrangement was come to involving certain amendments of the sliding-scale agreement. The terms of the new agreement will be made public as soon as they have been communicated to the firms affiliated to the Board.

Engineers' Demarcation Agreement.—The voting of the Amalgamated Society of Engineers on the trade demarcation agreement has resulted as follows: For, 18,096; against, 3,905. The agreement stipulates that there should be no stoppage of work on account of a demarcation dispute; that an endeavour should be made to settle the dispute immediately it arises in the works, and that failing such a settlement the recognised practice of the works should be continued pending a settlement by the committee appointed in terms of the agreement for dealing with disputes; that this committee should consist of three representatives nominated by the employers' local association and three representatives nominated by each of the societies concerned; that the decisions of the committee should be accepted by the parties as final and binding—all decisions to continue for a period of 12 months, and thereafter until brought up for review on three months' notice; that the application of the decision should be confined to the works in which the question arose; that the expense of the committee should be borne one-third by the employers' local association and the balance by the societies, according to the number of questions to which they have been parties. The agreement applies to Aberdeen, Dundee, Edinburgh and Leith, Clyde, Tyne, Wear, Tees and Hartlepool, Barrow, Liverpool, Birkenhead, and Hull.

Output and Accidents at Coal Mines.—The annual report of Mr. J. B. Atkinson, Inspector of Mines for the Newcastle district, has just been issued by the Home Office. The district embraces the counties of Northumberland, North Durham, and Cumberland, and in the year 1911 there were employed 98,765 persons below ground in the collieries of the district and 23,017 above ground, making a total for the whole area of 121,782 below and above ground. These figures show an increase of 2,550 in the number of persons employed as compared with the preceding year. During 1911 a total of 30,791,500 tons of coal were raised from the mines of the district, which shows a large increase as compared with the previous year. The reason of the increase is two fold: first, there were no strikes, such as in 1910 accompanied the inception of the Eight Hours Act; and, second, the three shifts of hewers introduced at many collieries in consequence of the Eight Hours Act has increased the output. A table is given showing the output of mineral per person employed, from which it is seen that the average for the district was 315 tons per person employed below and 256 per person employed above ground. A total of 513,149 tons of coal was obtained by coal-cutters worked by electricity in the district, and 1,132,715 tons by compressed air. One hundred and sixteen fatal accidents occurred, resulting in 122 deaths. The death-rate from accidents per 1,000 persons employed during the year 1911 is as follows: (1) Below ground, 1·07; (2) above ground, 0·69; (3) below and above ground, 1·00.

Standardisation in the Motor Industry.—Dealing with the subject of standardisation in "The Motor," Mr. Henry Sturmey considers that the Americans have a great advantage over us, for, whereas the production of even 1,000 cars to one model would be considered a very large number in a European factory, and is only reached, or exceeded, in very few concerns, the enormous home market at the door of the American producers make 10 times this number a by no means uncommon figure, even with comparatively new concerns. And in this matter, too, the American manufacturer has a further advantage over us, in the fact that a few general dimensions are standard throughout the trade, a fact which enables the producers of component parts to standardise and produce in large quantities, knowing that part so produced will fit, or be usable in, practically any United States car on the market. This, as Mr. Sturmey points out, is undoubtedly a great help to manufacturers of cars, who are enabled to purchase their components cheaper, and, what is almost of more importance, enables them to be more independent of the vagaries of the component maker. In illustration of the price advantage which this larger production on the part of the component maker gives to the builder, Mr. Sturmey mentions that an American manufacturer who purchases his engines can buy them at from 50 per cent. to 65 per cent. less than would be paid for similar engines of equal power over here, and so on throughout the machine, a fact which is, of course, reflected to the advantage of the motorist in the price of the cars.

British Trade with Russia.—H.M. Consul at Moscow, in his annual report, states statistics show that during the last five years imports into Russia from Germany, France, and the United States have made great advances, while British imports have remained almost stationary. Certain branches of industry which once were practically British monopolies are now being exploited by foreign competitors. This is especially the case with spinning machinery, which at one time was almost entirely in the hands of British firms. Of late, however, the German firms have entered the market. They can supply cheaper machinery, and, aided by their trade banks, can give longer credit than British firms are either able or willing to give. Although British supremacy in this line is not likely to be threatened, British firms will no longer enjoy the monopoly which once was theirs. It is impossible for British firms to grant the same credit as German and French firms which are supported by their local trade banks. In Moscow alone there are five German and two French trade banks, which shows the necessity for creating a British trade bank in Moscow to assist British firms. British firms are at last beginning to realise the necessity of printing their catalogues in Russian and of sending young employés to learn the language—a policy which has been advocated for years. A factor which tells against British firms lies in the immense advantage which the foreign commercial traveller, especially the German, possesses over the British, owing to the fact that English is hardly spoken at all in Russia, whereas German is widely known. The British traveller usually knows no Russian. A further factor which tells against British firms is the fact that they are often very badly represented by their foreign agents. In Moscow these are often Germans or German-Jews who will take an agency for a British firm simply for the sake of blocking it.

The Centenary of the "Comet."—An exhibition is now being held in Glasgow to celebrate the centenary of the "Comet," the first steam-driven vessel to run continuously in Europe. This vessel, which was, of course, propelled by paddles, ran for eight years on the Clyde, and was ultimately wrecked in December, 1820. To the United States belongs the distinction of having possessed the first steam propelled warship. The vessel, which was named the "Demologos," was designed by Robert Fulton in 1813, and was launched in October of the year following. It was a double-hulled structure, with the paddle wheel working in the space between them. She was 156ft. long, her sides were 5ft. thick,

and she carried twenty 32 pounder guns. The first British steam warship was a wooden paddle steamer of 238 tons, built at Deptford in 1822, and also named the "Comet." A little later a somewhat similar vessel, the "Monkey," which had been built at Rotherhithe in 1821, was purchased for the Navy. Some other notable dates in the development of the steam warship in Great Britain are as follows: 1840, first steam warships built from Admiralty designs; 1843, Her Majesty's paddle frigate "Penelope" built, first ship to be fitted with tubular boilers; 1842, Her Majesty's ship "Dwarf" (ex "Mermaid"), the first British screw-propelled warship, launched at Blackwall; 1843, Her Majesty's ships, "Jackal," "Lizard," and "Bloodhound," the first iron warships propelled by steam, ordered on the Clyde; 1863, Her Majesty's ship "Experiment," first twin-screw warship, built at Millwall; 1868, Her Majesty's ship "Penelope," first twin-screw ironclad, built; 1886, Her Majesty's ship "Rattlesnake" launched, the first warship to have triple expansion engines; 1899, Her Majesty's destroyer "Viper," first turbine-driven warship, launched; 1903, His Majesty's ship "Amethyst," first turbine-driven cruiser, launched; 1906, first torpedo boats burning oil exclusively launched; 1906, first turbine-driven battle-ship launched—His Majesty's ship "Dreadnought"; 1911, His Majesty's ship "Hardy," first destroyer with auxiliary motors for cruising, laid down. To-day over 150 ships built and building for the Navy are driven by turbines. A collier for the United States Navy, the "Jupiter," will be propelled by turbine-driven electric motors.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

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Water level indicating apparatus for steam boilers. Fukutome. 21201.
Valve mechanism of internal-combustion engines. Rowan. 21723.
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Water tube boilers. Yarrow. 23351.
Friction speed change gear. Patureau. 23486.
Means for regulating the supply of oil to internal-combustion engines. Bates & Hall. 24138.
Acetylene generators. Powell & Hanmer, Ltd., and Hanmer. 24212.
Internal-combustion motors. Losey. 24627.
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METAL QUOTATIONS.

TUESDAY, JULY 16TH.

Aluminium ingot	75/- per cwt.
„ wire, according to sizes, &c. ......from	102/- „
„ sheets „ „ ...... „	120/- „
Antimony .... £27/-/- to	£28/-/- per ton.
Brass, rolled	9¼d. per lb.
„ tubes (brazed)	11¾d. „
„ „ (solid drawn)	10d. „
„ „ wire	9¼d. „
Copper, Standard	£75/10/- per ton.
Iron, Cleveland	56/10½ „
„ Scotch	62/10½ „
Lead, English	£18/17/6 „
„ Foreign (soft)	£18/10/- „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£8/10/- per bottle
Silver	27⅞d. per oz.
Spelter	£26/-/- per ton.
Tin, block	£200/15/- „
Tin plates	14/7½ „
Zinc sheets (Silesian)	£29/5/- „
„ (Stettin; Vieille Montagne)	£29/7/6 „



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Edited by
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A New Method of Analysing Indicator Diagrams.

A NEW analysis of the cylinder performance of reciprocating engines is described by J. Paul Clayton, in Bulletin No. 58, just issued by the Engineering Experiment Station of the University of Illinois. The uses of the steam engine indicator have hitherto been mainly limited to determining the indicated horse-power of an engine, the setting of valves or the detection of serious leakages. But according to the author of this bulletin the indicator diagram may itself constitute sufficient evidence upon which to base an analysis of cylinder performance, the results of which have not heretofore been considered possible. The process involves the transferring of the indicator diagram to logarithmic cross-section paper, and the drawing of a figure called a logarithmic diagram. By the aid of this diagram, it has been found that the expansion and compression of all elastic media used in practice obey substantially the law $PV^n = C$, and from this fact are developed rational methods of approximating the clearance of a cylinder, of closely locating the cyclic events, and of detecting moderate leakage with the engine in normal operation. It is shown that the value of n is controlled directly in steam cylinders by the quality of the steam in the cylinder at cut-off, and that this relation of the value of n to the quality of steam is practically independent of size and speed for the same class of engine. It is claimed the method permits of the actual steam consumption of an engine being computed from the indicator card alone, to within 4 per cent. of the consumption as measured by test. The engine used was a long range cut-off Corliss engine, 12in. diam. by 24in. stroke, and some 60 selected tests arranged in 14 series—half with saturated and half with superheated steam — were used for the data on which the conclusions are based. Apart from abnormal influences, the value of n exhibited a large range of variation, from 0·70 to 1·34, the value being higher as the cut-off was lengthened. The quality of the steam was determined by the total weight of steam mixture present as steam at cut-off. The author claims that his

method is more accurate than the average test, since it virtually gives an instantaneous rate instead of an average quantity over a long time and thus enables a large number of points to be obtained for a water rate curve, while at the same time the tests are much less expensive and involve no change in the routine observed. Whether other steam engine experimenters will accept the author's conclusions and abandon existing methods in favour of his remains to be seen, but at all events it deserves attention, for a reliable test as ordinarily conducted is a laborious and somewhat expensive process. We cannot here enter into a precise description of the method of drawing the logarithmic indicator diagram. Its method of application resembles in some ways the use of the equilateral hyperbola familiar to all engine students, and may perhaps on that account be discounted, though the author points out the two are not comparable, and instances cases where the use of the equilateral hyperbola for purpose of comparison may be misleading, its only rational use, he asserts, being to determine roughly whether n is greater or less than 1·0, or for purpose of cylinder design in case of ordinary size of engines using saturated steam.

Thermal Efficiency.

FEW terms used in discussing the relative economies of various types of prime movers are more liable to abuse than the expression "thermal efficiency." It is trotted out as if it were an impartial and rigid measurement of fuel economy against which there could be no appeal. "Thermal efficiency" is simply the ratio of output to input in terms of heat units, and while the statement that the thermal efficiency of steam engines seldom exceeds 20 per cent. as compared with 25 per cent. in gas engines and 30 per cent. in oil engines may to thoughtless persons seem to imply marked inferiority in the former, often it is not really so if the cost of the fuel used be taken into account. In the steam engine the heat is nearly always derived from coal, which is so cheap that notwithstanding boiler and other inevitable losses it can, except in small sizes, easily beat an oil engine commercially owing to the much more expensive fuel the latter requires. Comparisons in fuels of totally different character are very misleading. Even fuels of the same kind may give false impressions. The Diesel engine and the motor-car engine are equally oil motors, but a comparison of their thermal efficiencies would be futile which did not take account of the cost of the fuels used, whether it be crude oil, petrol, or alcohol. The comparison of thermal efficiencies again is but one of many that must be made in determining all round efficiency or economy, for the latter word is capable of many definitions even when limited to the running of power plant. There is economy of capital, economy of labour, economy of maintenance, and these are so closely linked with each other and with wider questions that it is often difficult to disentangle them. A brief glance, however, is sufficient to show that the choice of a motor must be determined by a careful consideration of many things, and is by no means an easy question. It taxes in many cases the trained abilities of engineers, and can seldom be settled by a reference to a formula or any single definition of efficiency, "thermal" or otherwise.

PROFIT SHARING.

"THE Board of Trade Labour Gazette" gives an examination of the returns already received in connection with the enquiry into profit-sharing and co-partnership which is now being made by the Labour Department of the Board. It deals concisely with the first 100 schemes at present in operation. In few cases is the share in profits allotted to employés given as a matter of strict legal right; in the majority of cases the amount allotted for distribution as bonus is a fixed proportion of the profits, but in other participation stops at a certain point or a sum is given contingent on a certain rate of profit being earned. In a few cases a part of the profits of each year is carried forward in order to enable a bonus to be paid in an occasional bad year. The divisible profits for the purposes of the profit-sharing scheme are usually declared to be the clear or net profits, that is to say, the gross profits after deduction of rent, taxes, rates, wages, salaries, and other working expenses. As to the minimum remuneration of capital, interest at fixed rates is usually included among the deductions to be made before "net profits" are arrived at, this rate being generally 5, sometimes 6, per cent., and only exceptionally a lower or a higher percentage.

The proportion of the profits allotted for division between the employés varies very greatly in different schemes. In cases in which no mention is made of any part of the total net profits being retained for the employers as a reserved limit, there are a few cases of 10 per cent. of the profits being allotted as the share of the employés; a case of 5 per cent. is mentioned, and another, in which the share of the employés is 2½ per cent. of the divisible profits up to a certain sum, and 5 per cent. of the profits in excess of such sum. In a very small number of cases capital and wages share concurrently, the bonus being at the same rate on wages as the rate of interest received on the capital. It is, however, necessary to state that for the most part the returns in these cases contain no information as to the percentage in question.

Where a reserved limit is mentioned, the proportion of the surplus profits above this limit, which, so far as is known, is appropriated to the payment of bonus, varies from 5 up to 50 per cent., well over one-third of the schemes in question allotting the latter percentage, and nearly one other third giving from 20 to 25 per cent. In a certain number of cases the surplus is shared between capital and wages pro rata.

With regard to the division of the total bonus fund among the different employés, by far the most common method adopted is to divide this fund between the participants in proportion to the amount which each has earned in the period to which the distribution relates, no deduction being in many cases made for time lost by illness up to a certain limit; but in making the calculation overtime is excluded in a few cases, overtime and piecework in a considerable number of schemes.

In some cases all the employés without distinction are allowed to share in the bonus fund; but in many instances participation is confined to persons who possess certain qualifications, the most frequent of which is a certain length of service with the firm, varying from six months up to seven years, the most frequent period named being one year. In a few cases persons below a certain age are excluded, and in others persons receiving commission, piece-workers, or casual labourers. In certain instances conditions are attached to participation, by far the most frequent of which is the signing of a contract of service for a stated period, generally 12 months.

In about one-half of all the schemes the bonus is paid in cash; in a considerable number part is paid in cash and the remainder credited to a thrift fund available to provide provident benefits for the employés, this fund being usually deposited at interest with the employers. In a not inconsiderable number of cases the whole of the bonus, until the employé holds a certain amount of stock, is invested in the capital of the undertaking by which the participant is employed, and thereafter one-half, as a rule, is so invested, while the other half is either paid out in cash or retained on deposit with the employers. In a few schemes the whole of the bonus is invested in the shares or stock of the employing company. In a few cases shares obtained by the investment of bonus cannot be disposed of except with the permission of the employers.

As a rule, to which there are, however, important exceptions, the shares owned by the employés give them the ordinary voting powers, and as time goes on and their holdings increase, their voting strength should in due course be augmented. At present the proportion of the total number of votes that might be given at a general meeting of shareholders, which belongs to the employés, hardly ever reaches 5 per cent., and is in nearly all cases a quite insignificant percentage. In only six out of the 100 cases here dealt with are the employés represented on the board of directors. There exist, however, under a very large number of profit-sharing schemes, joint committees composed of employers and employed, whose functions, although of a consultative nature only, cannot be considered as other than important. The full report of the enquiry will, it is expected, be published in the autumn.

GAS ENGINES AND PRODUCERS FOR SHIP PROPULSION.

In the course of the discussion on the paper on the "Suction Gas Engine," by Mr. A. C. Holzapfel, read before the North-East Coast Institution of Engineers and Shipbuilders, and reproduced in our issue of April 26th last (see p. 509, Vol. XXIX.), Mr. A. E. L. Chorlton, of Messrs. Mather & Platt, Ltd., described a new and more simple form of gas engine than that given by Mr. Holzapfel in his paper, one particularly suitable for the duties of ship propulsion, and which had much impressed Mr. Holzapfel with its advantages over the more complicated engines of current practice. The description of this engine was, he said, apposite in view of what had been said about the high temperatures in gas engine cylinders, and the difficulties met in overcoming them. The temperature strain set up in the usual jacketed form of gas engine cylinder lead to possible cracks in working, as was well known, and the methods to overcome them, adopted in this type of engine, would, he felt, be interesting to marine engineers, and give them confidence in the use of such engines on board ship. Such strains in the first place arose through the practice of casting the liner and jacket of the cylinder in one piece, when, on the cooling of the casting, contraction strains were set up. Experience had shown that to obviate these successfully the jacket had to be entirely separate from the liner, both in casting and working. From the speaker's long experience with the land engine in most varied and onerous duties, certain conclusions in design were arrived at, all of which had greater simplicity than in current practice, as an essential principle. In making these observations, he (Mr. Chorlton) had in mind engines of comparatively large powers, *i.e.*, 2,000 b.h.p. and upwards. These conclusions referred to an engine of the 2-stroke cycle, vertical, double-acting open marine type, valveless, and having the jacket arranged as a separate casting or envelope. The initial engine of the vertical open marine type, as shown in Fig. 1, had now been at work over twelve months, and had been so successful that four others had since been supplied to the same firm. A high-speed enclosed forced lubrication engine of the same principle now at work had been reported on very favourably to Mr. Holzapfel, and was considered by him most suitable for working with the hydraulic transformer for ship propulsion.

About six years ago Mr. Chorlton had designed, and his firm constructed, a special 3-crank 2-stroke cycle marine engine, complete with producer, cooling and cleaning plant, exhaust boiler, and the necessary auxiliary, for ship propulsion. The many and varied experiences with this plant, most valuable in every way, convinced him of the ready applicability of the new design to ship work, and its superiority in simplicity and effectiveness, particularly so as the first engines built were of the exact marine type (triple expansion 3-crank). This view was confirmed by such marine engineers as had seen these engines at work, when their simplicity, ease of reversal, &c., were apparent. The "Duplex" cylinder was shown in section in Fig. 1, surrounded by the plain tank-like jacket.

The engine might be briefly described as of the vertical double-acting 2-stroke cycle type, in which every stroke was a driving stroke.

The power cylinders were arranged for the admission of air and gas without the use of any valves. The incoming charge was controlled by one piston, and the burnt gas exhausted by the other through peripheral ports in the centre of the cylinder wall, thus obviating the use of both inlet and exhaust valves. The cylinders were of the simplest construction, of U form, one inverted over the other, the whole bolted together and contained in a water tank. There were no cylinder covers, the usual irregular combustion chamber was entirely dispensed with, and there were no joints under expulsion pressure. Pumps for the supply of air for scavenging and mixing and for gas supply were arranged alongside the power cylinders. As the piston reached the end of its expansion stroke the air pump delivered a scavenging charge of air only, which scoured the products of combustion out of the power cylinders through the exhaust ports. Thereafter the gas pump delivered its supply of gas automatically, simultaneously to the power cylinder, in readiness for the compression stroke.

Speaking further on the marine application of gas engines, it was Mr. Chorlton's experience, and it appeared also Mr. Holzapfel's, that the gas producer had been responsible for the greatest difficulties in the propulsion of ships, it being of simple land design, and not considered sufficiently in combination with the engine. A gas producer specialist could be found, and an engine specialist, but a specialist combining these was unfortunately rare. Consequently the users fell between two stools. There was unquestionably the talent in the United Kingdom to accomplish, when combined, a highly successful result in marine work. Yet through this lack of combination, foreign countries were being constantly looked to for new ideas and designs. Undoubtedly, in England, the subject of marine propulsion by gas engines had not been adequately studied, as it was overshadowed by foreign oil proposals. British engineers had not given it nearly the same consideration that marine propulsion by the triple expansion engine or the turbine had received. If they could be induced to specialise in marine gas engines and producers, many difficulties at present insurmountable to their eyes would disappear.

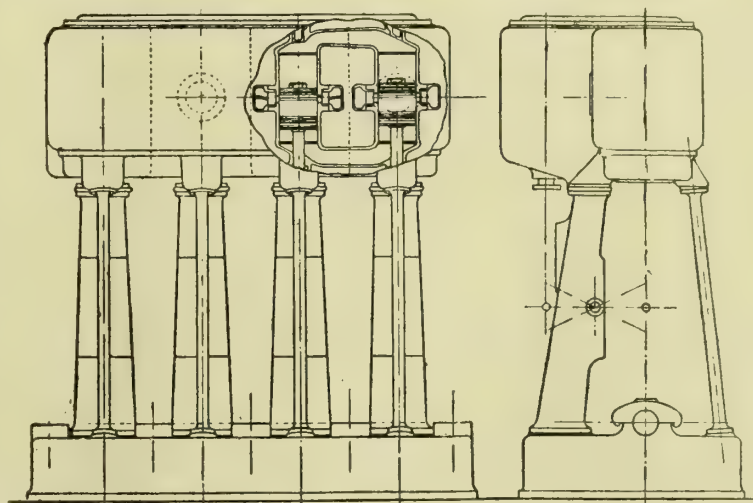


FIG. 1.—MARINE TYPE TWIN DUPLEX GAS ENGINE.

It seemed astonishing to the speaker that when coal, the life-blood of the country, could be obtained at 10s. per ton, more thought was not being given to its use as gas power, especially when that price was compared with the high comparative cost of oil, taking due account to the thermal values of the two. Mr. Chorlton, in conclusion, said Mr. Holzapfel was endeavouring to bring home to the shipping public the great economical possibilities of gas power from coal, and while greatly appreciating the value of that gentleman's work was also fully aware of the large and powerful interests of the oil firms he had to fight.

Mr. Stainer Hutchins, of the Power-Gas Corporation, said that the experience gained with at least two of the forms of propulsion referred to was probably not sufficient to enable comparisons to be drawn, and to anyone who had not followed the developments in the gas propulsion of vessels it would appear, when reading Mr. Holzapfel's paper, that very little work had been done under that head. Having been in constant touch with Mr. Holzapfel since the "Holzapfel I." was built, Mr. Hutchins could safely say the author of the "Suction Gas Engine" had put his paper forward in this way because of his desire to draw attention to the points where improvements were mostly required, and not—as was usually the case—to give results of successes. It no doubt appeared to many that to adopt a simple non-bituminous plant from land to marine purposes was an easy problem, but doubtless in practice it had been found to be the reverse. Some years ago he had studied the question very deeply in conjunction with Mr. J. B. Wilkie, engineer to the Elder Dempster Company, and as a result a producer had been designed which was coupled to a double-acting two-cylinder engine. The

arrangement of this engine was such as to enable it to reverse. This combination was fitted in a vessel and a number of tests were made upon the Thames. Another producer of this type, but of a smaller capacity, had been sent out to New Zealand to be installed in a boat for river work. Producers suitable for marine work should have special arrangements for clinkering, as the space available for such work could not be so great as on land. The vaporiser also should be of special design to prevent the accumulation of water at one end or one side when the vessel had either a constant list or was rolling, &c. Top poking in most cases would be impossible, and therefore facilities for searching practically the whole of the fire should be arranged for from the bottom; yet space was extremely limited and poking from the bottom and ashing should, for obvious reasons, be all done from one side. This, when anthracite or non-bituminous coal was used, caused trouble and difficulty through being unable to withdraw the clinker, &c., from the back of the producer, which could only be overcome by a special arrangement of brickwork. Owing to the small head room, special grates had to be used, and if these were not specially designed the result was that they were very quickly burnt out. If this should happen at sea it might easily spell disaster.

In dealing with the question of utilising bituminous coal all the difficulties in the producer designed for non-bituminous coal plus the removal of the tar and greater percentage of dust were encountered and also more clinkering. It was not an uncommon thing for even engineers to imagine that all bituminous coal was alike; that was far from the case—it varied considerably. His company, the Power-Gas Corporation, had at their disposal the experience of twenty-five years of work on bituminous gas-plants, and during that time many types had been tried—up and down blast, double blast, &c.—yet from the gasification of the usual marketable bituminous coal they had only found the type of that originally designed by Dr. Ludwig Mond to be commercially satisfactory.

The problem to be faced was that of combining certain of those parts which compose the land producer (and which had been tried and proved satisfactory for so many years) into a producer suitable for marine work. It was obvious that it would be necessary to eliminate certain of the parts contained in a land producer and to replace them by others occupying less space. As Mr. J. Archer had pointed out, efficient tar extractors could be obtained—so that there was no need to complicate the producer or generator by attempting to destroy the tar within it. The following table gave the results of a test of a special fan, and it was apparent from these figures that by putting two in series the tar remaining would be so small that it could be dealt with in a very simple way.

Date.	Conditions of Test.	Temp. Leaving Coolers.	Temp. Entering Fan.	Temp. Leaving Fan.	Pressure Entering Fan.	Pressure Leaving Fan.
		Degrees Cent.	Degrees Cent.	Degrees Cent.	Inches.	Inches.
Nov. 7	Running on ...	26	26	13	1·75	11
Nov. 8	Unwashed gas ...	21	21	15	1·75	11
Nov. 9	From coolers ...	21	21	15	1·75	10

Fan Revolutions.	Water Gallons per Hour.	Water Entering.	Temp. Leaving.	Tar in Gas. Entering.	Tar in Gas. Leaving.	Extraction.
		Degrees Cent.	Degrees Cent.	Inches.	Inches.	Per Cent.
2,600	270	8	13	1·76	·034	98
2,600	180	8	14	1·70	·043	97·5
2,600	120	7·5	14	1·27	·099	92·2

Mr. Hutchins, in conclusion, stated that knowing the difficulties of marine work as they did, neither his company nor himself anticipated any great difficulty in manufacturing a producer suitable for marine work. It should not, however, be thought that they were content in simply resting upon their experience and the proved parts composing their standard plants, as they had under consideration and test a special type of generator which appeared to have many peculiar advantages, making it available for marine purposes; also, a special combined gas-cooler and tar-extractor.

A NEW DYNAMOMETER CAR.

A NEW dynamometer car has recently been completed at the Topeka shops of the Atchison, Topeka, and Santa Fé Railway. The general arrangement of the car is shown in the accompanying illustrations, for which we are indebted to "The Railway and Engineering Review." The underframe, side and roof frame are built entirely of steel, and the length over end sills is 50ft. and the extreme width 10ft. The working end of the car is 25ft. in length and contains the dynamometer, recording apparatus, switchboard, gauge board, and work benches. The trucks are of the 4-wheel arch bar type, with heavy elliptical springs and extra heavy arch bars. The wheels are 34in. diam. and are steel tyred. The car is lighted by electricity from an axle lighting system. The heating system consists of a stove and steam coils.

The dynamometer is of the double diaphragm type, recording both drawbar pull and buff. The lever arms, with a ratio of five to one, are connected at one end to a filler block in the yoke, and at the other end to a double piston, 20in. diam., whose heads press against blind rubber gaskets,

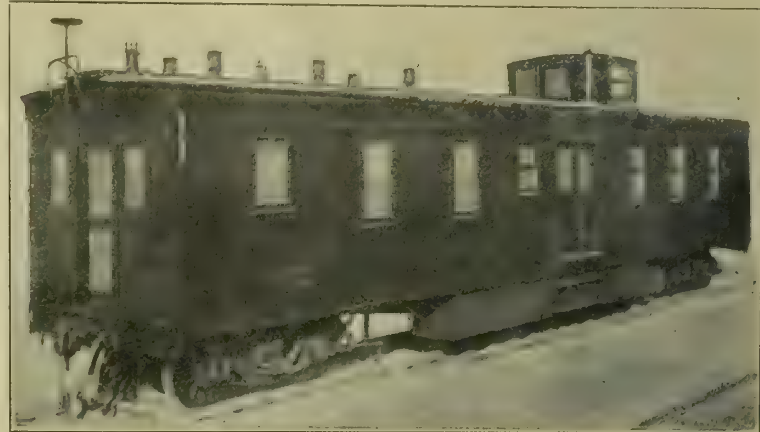


FIG. 1.—DYNAMOMETER CAR.

covering the liquid chambers. The piston is suspended by means of knife edges, in order to eliminate all friction. The bearings for the arms are made by means of small hardened tool steel pins surrounding the main pin. A mixture of glycerine and alcohol is used in the liquid chambers. These latter are connected to the recording apparatus and gauge board by $\frac{3}{4}$in. copper pipes. When the dynamometer is not in use the arms are brought to centre and held by four small jacks between the top of arms and cylinder casting. The dynamometer is so designed as to safely take and record a shock of 1,000,000lbs. at the drawbar.

The recording apparatus is placed just back of the dynamometer. The following records may be made on the chart: (1) Curve of drawbar pull; (2) curve of drawbar buff; (3) curve of speed; (4) record of time, either by five seconds or half seconds; (5) record of position of mile posts, stations, &c.; (6) record of throttle opening; (7) record of reverse lever; (8) record of boiler pressures; (9) record of indicator cards; (10) record of train line pressure; (11) record of brake cylinder pressure; and (12) record of coal or oil fired.

The apparatus is mounted on a heavy iron baseplate through which a driving shaft passes from the auxiliary truck below. The auxiliary truck has two 22in. wheels with 9in. flat tyres. It is connected with the main driving shaft through a train of bevel gears, running in oil, and a universal joint. This auxiliary truck may be raised or lowered from within the car. A motor is also provided for driving the recording apparatus. Three speeds are provided for the motor drive and three for the auxiliary truck drive, it being the intention to use the auxiliary truck drive in rating work and general engine tests, and the motor drive in special air brake and draft rigging tests. By means of two conveniently located levers and clutches it is possible to quickly change from one drive or one speed to another. The drive is so connected

that reversal of direction of the car movement does not reverse the direction of chart travel.

The records are made on a chart 15in. wide, which is drawn over the table by means of friction, between two gear connected rollers. Both originating roll and receiving roll are located at the back of the machine where they can be readily removed

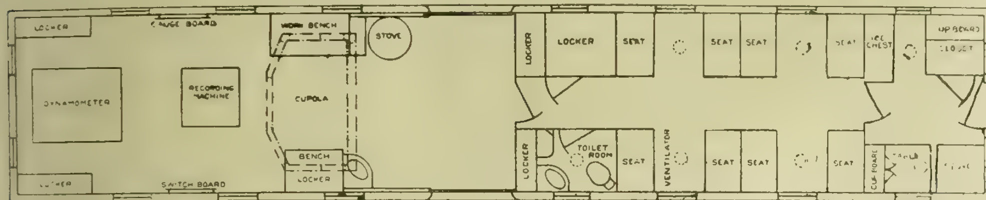


FIG. 2.—PLAN OF DYNAMOMETER CAR.

or put in place. All curves are drawn by pens attached to hollow aluminium rods running at right angles to the paper. All datum line pens are connected to a single cross bar at the front, their records being made an inch in front of those made by the recording pens. The pens consist of small brass cups with phosphor bronze troughs, which carry a thread wick from the barrel to the point, and will draw a line moving sideways as well as forward.

The pressures from the dynamometer are transmitted to standard outside spring Crosby indicators on one side of the recording table, it being the intention to put in different weights of indicator springs to suit the various classes of work. The curve of speed is obtained from a Boyer speed recorder located in the base of the recording apparatus and chain driven from the main shaft, it being so arranged that it may be driven at double its normal speed in freight service and at normal speed in passenger service, thus giving a large off-set at low speeds when desired. The time record is drawn on one edge of the chart by means of a pen connected to a small electric magnet, which in turn is operated from an electric clock. Off-sets of one minute, five seconds, or one-half second may be obtained. The record of locations is made by a small electric magnet in connection with a push button running to the observation cupola above. The cupola is provided with an electric searchlight for night work. The records from the locomotive are also made by means of electric magnets similar to that used in the location record. Two pens connected to standard Crosby indicators on the side of the table give a continuous curve of air pressure in the train line and in the brake cylinder, or, if it is so desired, in the auxiliary or supplementary reservoirs.

The gauge board contains the following apparatus: One standard clock; one Haushalter speed recorder, driven from main truck; four air recording gauges; four standard air gauges; one gauge for dynamometer, showing drawbar pull; and two electric counters.

Electricity for the lighting of the car and the operation of

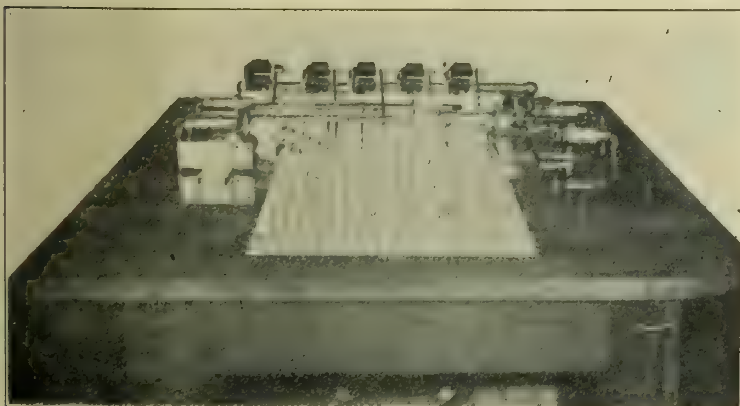


FIG. 3.—RECORDING TABLE, DYNAMOMETER CAR.

all magnets and motors is obtained from a set of 16 storage cells, located beneath the car. These in turn are charged by means of a Bliss generator, driven from the rear truck of the car. The voltage used throughout is 32. The switchboard is so arranged with a series of multiple jacks that it is impossible to put any voltage on any magnet, thus making the whole arrangement very flexible and convenient. The total weight of the car is 91,000lbs.

THE SINTERING AND BRIQUETTING OF FLUE DUST.*

BY FELIX A. VOGEL.

FLUE dust, to most blastfurnace operators, means a troublesome by-product, the formation of which should be curtailed, if not eliminated entirely. However, with the increasing use of fine ores, larger furnaces, and high-pressure blast, the production of flue dust is constantly increasing. As a result of greater economy in the iron industry, attention has been directed towards the utilisation of this enormous amount of waste material.

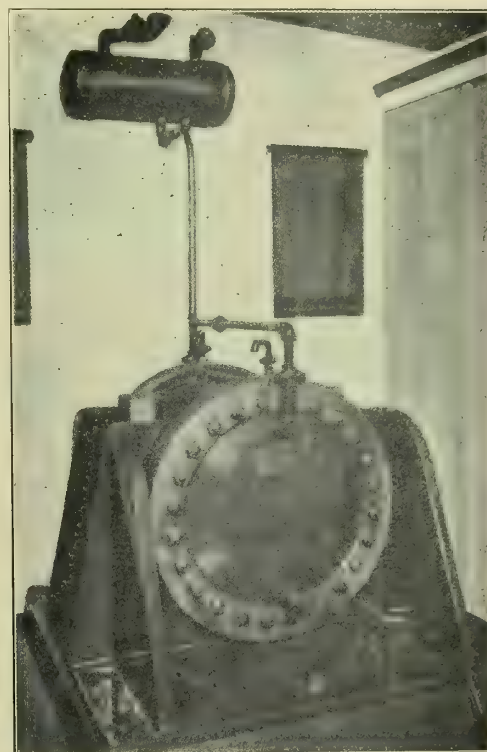


FIG. 4.—VIEW SHOWING DYNAMOMETER IN POSITION.

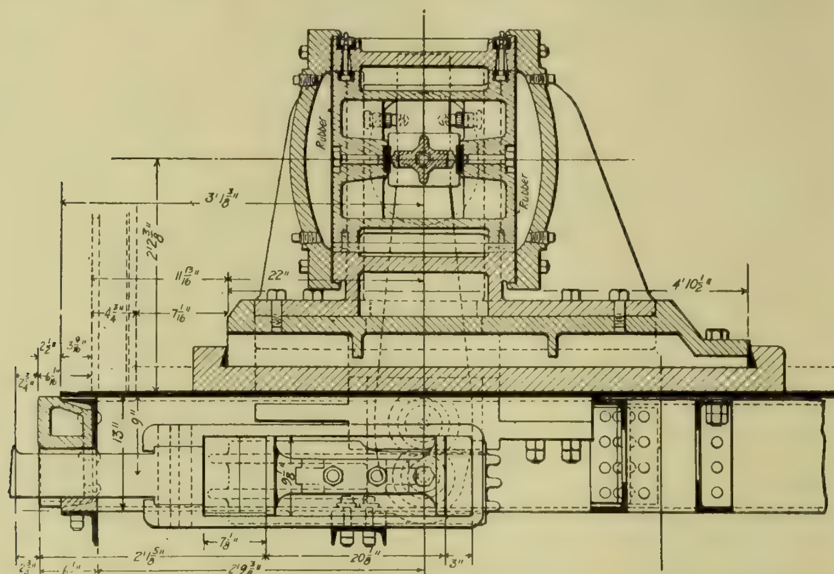
Flue dust is generally a fine material containing considerable coke and iron ore, with a small admixture of lime and silica, depending upon the burden. The iron ore is partly reduced, which shows that it originates largely from the reducing zone of the blastfurnace. This dust usually contains 20 per cent. of coke and more than 40 per cent. of iron, and unless made available represents so much loss. This accounts for the first efforts to re-charge the flue dust into the furnace, either by moistening it down with an excess of water, or mixing it with clay to form balls or pulp, or treating it with limewater.

These methods, however, have been practically discarded, as they failed to produce the desired economies. To recover, in the blastfurnace, all the values represented by the material contained in the flue dust, the following conditions should be complied with. (1) The dust should be agglomerated into lumps about the size of furnace coke, so that it will help to carry the burden and facilitate the flow of the gases. (2) The agglomerated material should be strong enough to carry the burden without disintegrating; it should be heavy so as to decrease its volume, and it should be sufficiently porous to permit the furnace gases to penetrate fully. Under no condition should the surface be glazed. (3) It should contain all of the valuable constituents of the dust, such as coke, iron ore,

* Abstract of paper presented at the New York meeting of the American Institute of Mining Engineers.

lime, &c. (4) It must stand handling without undue breakage, and should not produce more than 5 per cent. of dust. (5) It must stand the weather. (6) It must not disintegrate in the blastfurnace before being greatly or totally reduced. (7) It must submit to easy reduction without requiring additional fuel. (8) It must not contain substances detrimental to blastfurnace operations. (9) Its cost of production must be low.

Blastfurnace operations, by the use of such agglomerated material, will result in: (1) Regular, steady operation. (2) Increased burden, increase in the yield and metal produced. (3) Decrease in the consumption of coke. (4) Decrease in the production of flue dust. (5) Decrease in the cost of producing pig iron.



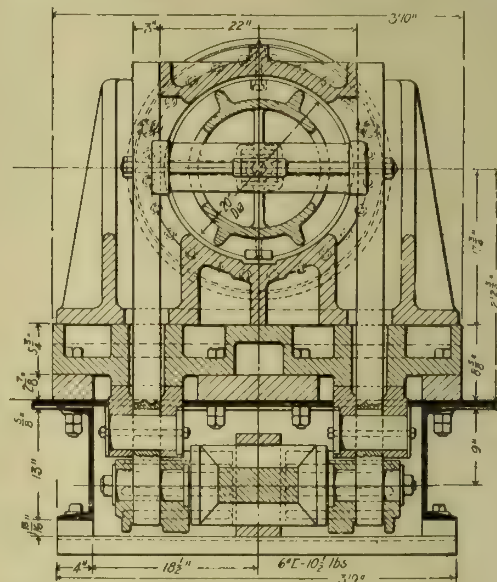


FIG. 5.—GENERAL ARRANGEMENT OF DYNAMOMETER.

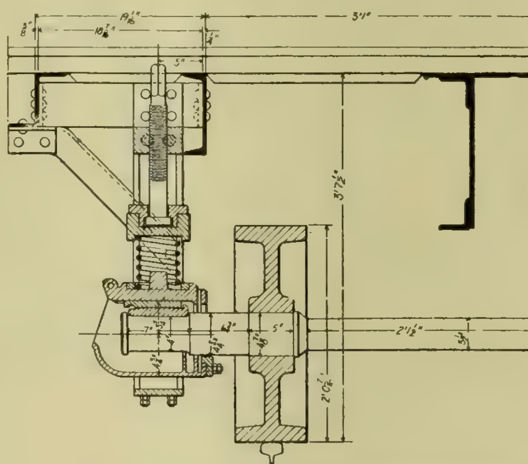
In order to obtain these results American and European metallurgists have followed two different lines. In the United States it has sufficed to save the iron content only, though not in the best possible form, while in Europe the endeavour has been to make a high-class product which would meet all the conditions above enumerated.

A number of processes have been evolved in the United States, generally known as agglomerating and sintering processes. They are based on fritting together the particles of ore by heat, the binding action being due to the formation of silicates, mostly of iron. When the coke has not been eliminated mechanically from the dust, it is burned out, leaving ashes in the agglomerated material, which increases the formation of silicates of iron or glazing material. In some cases, however, more fuel is added to the flue dust, which, naturally, further increases this drawback.

The nodulising process, the oldest process in the United States, has been in successful operation for a number of years. Flue dust is treated either directly, or it is previously submitted to a magnetic separation to eliminate coke and lime. This is done to facilitate the subsequent nodulising operation, which is carried on in a slowly rotating cement kiln from 80ft. to 120ft. long. From 200lbs. to 300lbs. of finely-powdered coal is used per ton of finished material, the coal being blown into the kiln. Gas and oil have also been tried with more or less success. The heat produced is considerable and difficult to control, the semi-soft material formed consisting of iron ore particles and slag, which by the revolving action of the kiln is balled together in nodules of various sizes—from a pinhead to that of a cannon ball—which are usually quite dense, often fused and glazed. They contain from 60 to 67 per cent. of iron, which makes them quite attractive from the furnaceman's point of view. To make nodules an elaborate and expensive plant is required, the operation of which is more or less difficult and costly.

The Huntington-Heberlin pot process, which has been used with good results in the roasting of pyrite cinders, has been recommended for the fritting of flue dust. The resulting fritted material is of more or less cellular structure. However, this would not be an advantage, as the surface would be largely glazed, rendering it not permeable to gases, and would have to be removed in the blastfurnace at about smelting heat. The process is somewhat simple, requiring stationary iron pots fitted with a perforated false bottom through which the air is blown into the charge. The equipment is cheap; the operation, however, is not continuous, which makes it expensive.

The Groendal briquetting process has also been applied to flue dust. The flue dust, either moistened, or after the elimination of the coke and stone, is pressed into bricks which are subsequently fritted in high temperature. To facilitate the operation it was found necessary to eliminate the coke; this, however, increases the cost. The separated coke is of little value, since it contains many impurities. The machines used are ordinary brick presses. The bricks are carefully placed in layers on cars, which are run into long kilns about 170ft. long, where they are submitted to high heat, gas being used for the purpose. The platforms of the cars are built of firebrick and form the bottom of the kiln. The highest temperature, about 1,300° C. or 1,400° C., is reached in the centre of the kiln, the highly-burned briquettes working gradually towards the cooler end of the kiln, where they are finally unloaded. The operation lasts about seven hours. The resultant briquettes contain from 65 to 70 per cent. of iron with practically no impurities, these having been eliminated. No ashes are left by the fuel. The briquettes are only slightly fritted, are very porous and friable, and make a high-class material for use in an open-hearth furnace. The manufacture



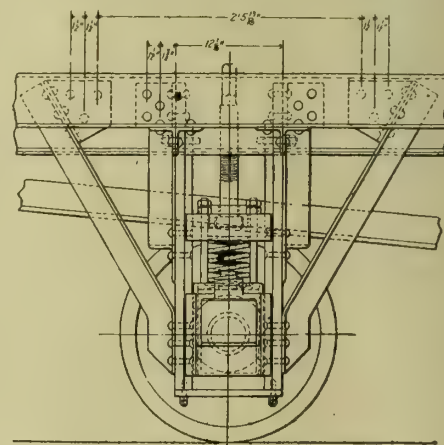


FIG. 6.—AUXILIARY TRUCK, DYNAMOMETER CAR.

of Groendal briquettes is expensive, necessitating a costly plant, which has limited output. A ton of flue dust will produce about two-thirds of its weight in briquettes.

Quite recently the Dwight-Lloyd process has been applied to the sintering of flue dust. The material is submitted to internal combustion in layers of from 5in. to 7in. thick. It is fed on an endless conveyer formed of iron pallets or grates. After the fuel therein contained has been ignited by means of a gasoline torch, or some other device, the air is drawn through by suction. The operation lasts about 20 minutes. A good deal has been published of late in regard to this process. It is claimed that the required plant is not costly, while the operating expenses are considerably lower than in the previous process. The resultant sintered material is not homogeneous and, while a large portion of it is of cellular structure, it is glazed on the surface, which makes it quite difficult to reduce in the blastfurnace.

The Greenawalt process uses much the same apparatus as the Heberlin pot, but air is drawn through the charge similar to the Dwight-Lloyd process. The sintered material from these various processes is expensive on account of the loss of carbon and, with the exception of the Groendal briquette, is not of good physical structure and is usually glazed on the surface. The briquetting of flue dust has been more attractive abroad than has the sintering.

The lime process mixes the flue dust with from 5 to 10 per cent. of hydrate of lime and, after briquetting the material, is exposed to the air for a certain length of time, so that a carbonate is formed which is the binding medium. This binder will eventually act as flux and will replace a certain amount of stone. The process, while having decided advantages, is quite cumbersome and costly, as the briquettes must dry from two to four weeks under cover.

The pioneer process uses sulphide pitch, obtained from the sulphide pulp mills, as a binder. It is an organic substance, rich in carbon and hydrocarbons, which will burn readily and thus increase the caloric value of the material. The flue dust is pressed into briquettes with from 4 to 8 per cent. of sulphide pitch; they are quite hard and give fair results, but the process is expensive.

The Ronay process does not use a binder. The flue dust is submitted to a very high pressure in a specially-constructed type of hydraulic press; the resulting briquettes can be handled immediately and have proved very satisfactory. The process requires an expensive plant, however, increasing the operating cost.

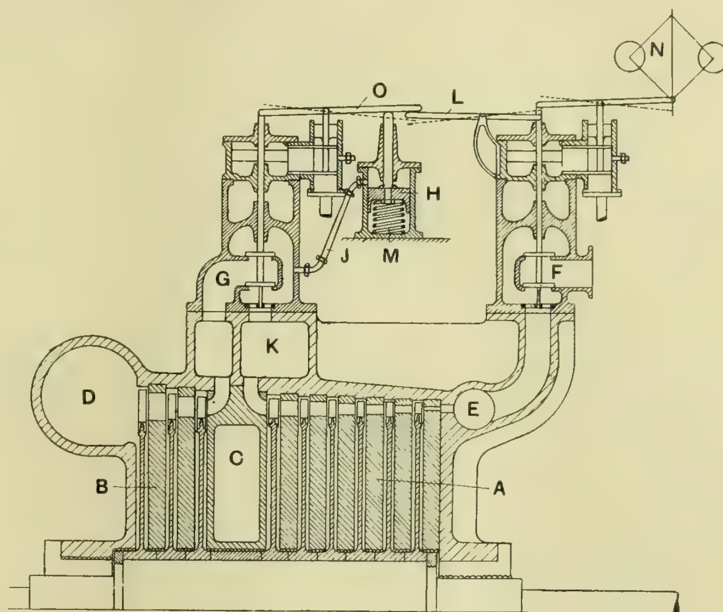
The Schumacher process does not use what may properly be called a binder, but is based on the latent cementing actions existing in fresh flue dust and which are made active by the presence of a small amount of a catalytic substance. Thus 0·25 per cent. of magnesium chloride mixed with fresh flue dust and from 6 to 10 per cent. of water, pressed into briquettes, will create a strong reaction, noticeable by the considerable heat developed; the briquettes will be perfectly set and hard within a few hours. The process is very simple, an ordinary pug mill being used in which to mix the material, which is subsequently pressed into briquettes in a toggle press and then loaded on cars to allow them to set. Some flue dust will react so strongly that a large amount of ore or coke breeze may be added to the briquettes; in these cases the flue dust acts as a binder.

The Schumacher process requires an inexpensive plant and the cost of manufacturing is low. It is extensively used abroad and has replaced some of the other methods. The briquettes of all-agglomerated materials have given most satisfactory results abroad and highest returns and values to the blastfurnace operators.

VALVE GEAR FOR STEAM TURBINES.

An arrangement of valve gear for condensing steam turbines for use in paper mills and elsewhere, where in addition to power production steam is required for drying or heating purposes, is shown in the accompanying sectional view. In this arrangement, the joint invention of Mr. W. J. Parkyn, of Messrs. D. Adamson & Co., Dukinfield, and Mr. T. D. Nuttall, of Messrs. Bentley & Jackson, Ltd., Bury, the main throttle valve can be opened by the governor without necessarily affecting the bye-pass valve which controls the supply of steam from the heaters or drying cylinders to the low pressure turbine, but the act of closing the main valve will close the by-pass valve also. The object of the gear is to keep the pressure constant in the heaters independent of the load of the turbine; to by-pass and utilise through the low-pressure part of the turbine any extra steam which may not be required in the heaters; and further, to obviate racing by keeping the by-pass valve under the control of the speed governor, so that no steam can pass from the heaters through the low-pressure part of the turbine when the machine is running with no load.

The illustration shows an impulse turbine of the usual type fitted with the valve gear and regulating mechanism. The turbine is divided into two parts A and B by a blank diaphragm C, which is provided with ports and channels which convey the steam from the high-pressure part A of the turbine to the chamber K, which supplies the heaters or drying cylinders. From the heaters the steam passes to the low-pressure part B, through the by-pass valve G (actuated by an oil relay), and then to the condenser D. The valve G is controlled by a lever O, which is loose at one end, and can be lifted separately either by the piston H of a pressure regulator or the high-pressure throttle valve F through the lever L. The



VALVE GEAR FOR STEAM TURBINES.

piston H is controlled by the steam, flowing from the chamber K to the heaters, passing through the pipe J on to one side of the piston, and acting against the resistance of the spring M adjusted to the tension required to balance the initial pressure in the heaters. The high-pressure throttle valve F is controlled by the speed governor N either directly or through an oil relay.

In operation, high-pressure steam is admitted through the throttle valve F controlled by the governor N to the chamber E, and then passes through the high-pressure part A of the turbine to the chamber K, which supplies the heaters. When the required pressure in the heaters is obtained the steam pressure forces down the piston H against the resistance of the spring M and frees the lever O, which in turn allows the by-pass valve G to open and steam to pass from the heaters to the low-pressure part B to the condenser D, thus utilising any steam not required in the heaters. This, however, can only take place when the governor N is running slow, because the lever L, which holds up the lever O when the governor is in its top position, would then be lowered, and so allow the lever O to fall. It will thus be seen that the gear is so arranged that when the governor N is in its top position and running at its quickest speed the valve G cannot be opened. It will further be observed that the low-pressure or by-pass valve G is not always under the influence of the governor, but that the governor only acts upon this valve in case of a runaway of the turbine, in which case the governor closes both the main throttle valve L and the by-pass valve G in order to prevent steam being by-passed from the chamber K (supplying the heaters or drying cylinders) into the low-pressure portion D of the turbine.

THE CHEMICAL AND MECHANICAL RELATIONS OF IRON, VANADIUM, AND CARBON.*

BY PROF. J. O. ARNOLD AND PROF. A. A. READ.

THE influence of vanadium on iron and steel was discovered by one of the authors in the steelworks of Sheffield University during a series of researches carried out from 1899 to 1902. The experiments were made on ingots melted by the Huntsman crucible process, and in the acid open-hearth furnace. The results were not published in any journal, but were copyrighted at Stationers' Hall. The influence of vanadium, *per se*, was not very marked on structural steel, but in the presence of chromium, nickel, and tungsten, the results were almost magical. On tool steel, *per se*, and with other elements, the results were startling. It was pointed out that as the carbide residue on dissolving the steel in dilute sulphuric acid contained nearly all the vanadium, this element probably existed

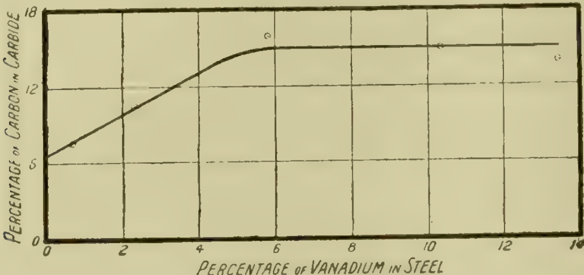


FIG. 1.

in the form of a carbide, or double carbide; but so far no systematic research has been carried out to determine the exact condition in which vanadium may be present in steel. The present communication is a continuation of the work published by the authors in their papers on "The Chemical Relations of Carbon and Iron,"† "The Chemical and Mechanical Relations of Iron, Manganese, and Carbon,"‡ and "The Chemical and Mechanical Relations of Iron, Chromium, and Carbon,"§ and contains an account of a number of experiments made to determine: (1) The composition of the carbides separated from a series of well-annealed steels containing various percentages of vanadium, the percentage of carbon increasing with the percentage of vanadium. (2) The mechanical properties of the alloys under static and alternating stress tests. (3) The microscopical features of the alloys.

Method of Manufacture of the Authors' Steels.—The alloys were made by the coke crucible process in Sheffield white clay pots from Swedish bar iron, American washed iron, and 38 per cent. ferro-vanadium; 0·05 per cent. of metallic aluminium was added to each a few minutes before teeming. The ingots, $2\frac{3}{4}$in. square, and each weighing 40lbs., were cogged and hammered into bars $1\frac{1}{8}$in. round. The bars were heated to about 950° C. for six hours, and were allowed to cool during an additional 12 hours.

TABLE I.

Number of Steel.	Carbon per Cent.	Vanadium per Cent.	Silicon per Cent.	Phosphorus per Cent.	Manganese per Cent.	Sulphur per Cent.	Aluminium per Cent.
1315	0·60	0·71	0·05	0·01	0·06	0·04 or under	Under 0·01
1316	0·63	2·32	0·09	0·01	0·07		
1309	0·93	5·84	0·21	0·02	0·11		
1310	1·07	10·30	0·32	0·03	0·12		
1312	1·10	13·45	0·47	0·03	0·12		

Chemical Compositions of Authors' Series.—The analyses of the steels were made on the last turnings from the carbide bars. The results are given in Table I.

Determination of the Carbides.—The method and treatment used for separating the carbides was the same as described in the author's last paper, already referred to*, but with this modification, that the residues were dried at 100° C. in a current of hydrogen, the tube being pumped out from time to time. The steels dissolved quite readily, and with each member of the series vanadium was found in the hydrochloric acid solutions; but in most cases it was quite unnecessary to test for vanadium, as the electrolyte was distinctly blue to dark blue in colour.

The carbides obtained from Nos. 1315 and 1316, contain-

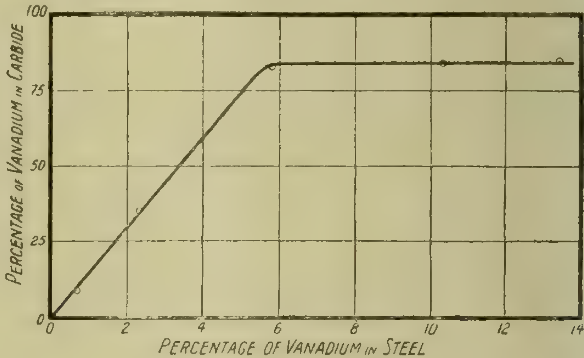


FIG. 2.

ing 0·71 and 2·32 per cent. of vanadium, were dark grey; and from Nos. 1309, 1310, and 1312, containing 5·84, 10·30, and 13·45 per cent. of vanadium, slate grey in colour.

TABLE II.

No. of Steel.	Carbon per Cent.	Vanadium per Cent.	Amperes.	Volts at Terminals.	Time in Acid.	Grammes Dissolved.	Weight of Dry Residue.	Percentage of Total Carbon obtained with Carbide Residue.	Analysis of Carbide. Carbon per Cent.	Analysis of Carbide. Iron per Cent.	Analysis of Carbide. Vanadium per Cent.	Corresponding to the Formula.	Theory. Carbon per Cent.	Theory. Iron per Cent.	Theory. Vanadium per Cent
1315	0·60	0·71	0·5	0·6 to 1·5	12 hours	8·920	0·6753	95·77	7·61	83·71	8·68	$11Fe_3C+V_4C_3$.	7·57	83·24	9·19
1315	0·60	0·71	0·5	0·6 to 1·5	12 hours	8·926	0·6847	96·98	7·66	83·69	8·65				
1315	0·60	0·71	0·5	0·6 to 1·5	11 hours	8·260	0·6154	92·71	7·49	83·27	9·24				
1316	0·63	2·32	0·5	0·7 to 1·2	11 hours	8·054	0·4346	88·10	10·66	54·60	34·74	$2Fe_3C+V_4C_3$.	10·00	56·00	34·00
1316	0·63	2·32	0·5	0·7 to 1·2	11 hours	8·053	0·4148	82·80	10·44	54·71	34·85				
1316	0·63	2·32	0·55	0·7 to 1·2	10 hours	7·630	0·4180	91·20	10·63	53·30	36·07				
1309	0·93	5·84	0·5	0·8 to 1·3	12 hours	8·625	0·5066*	99·15	15·94	0·54	83·52	V_4C_3.	15·00	—	85·00
1309	0·93	5·84	0·5	0·8 to 1·3	12 hours	8·612	0·4973*	98·19	15·94	0·47	83·59				
1309	0·93	5·84	0·5	0·8 to 1·3	12 hours	8·313	0·4890	97·63	16·05	0·83	83·12				
1310	1·07	10·30	0·5	0·8 to 1·4	12 hours	8·168	0·5952	96·76	15·03	1·04	83·93				
1310	1·07	10·30	0·5	0·8 to 1·4	12 hours	8·160	0·5732*	95·22	15·00	0·63	84·37				
1312	1·10	13·45	0·5	0·8 to 1·6	12 hours	8·303	0·6757*	99·78	14·12	0·82	85·06				
1312	1·10	13·45	0·5	0·8 to 1·6	12 hours	8·571	0·7267	99·06	13·76	1·27	84·97				

* These carbide residues were boiled for one hour with dilute sulphuric acid (1 of acid to 10 of water), then washed, treated, and dried in the usual way

The analyses of the carbides were carried out as follows: The porcelain boat containing the dried carbide was weighed. About one-half of the carbide was carefully removed and put on one side for the determination of iron and vanadium. The boat was again weighed, the carbide well mixed with pure manganese dioxide, and the carbon estimated by direct com-

* Abstract of paper read before the Iron and Steel Institute.
† "Transactions of the Chemical Society," 1894, p. 788.
‡ "Journal of the Iron and Steel Institute," 1910, No. 1, p. 169.
§ "Ibid.," 1911, No. 1, p. 249.

* "Journal of the Iron and Steel Institute," 1911, No. 1, p. 219.

bustion. The remaining portion of the carbide was intimately mixed with sodium carbonate and a small quantity of sodium peroxide in a platinum basin, and heated in a muffle furnace. When cold the mass was repeatedly boiled with water and filtered. The vanadium in the filtrate was estimated by reducing with sulphurous acid and titrating with a standard solution of potassium permanganate. The residue on the filter paper was dissolved in hydrochloric acid and made up to a known volume. The iron was then estimated by the

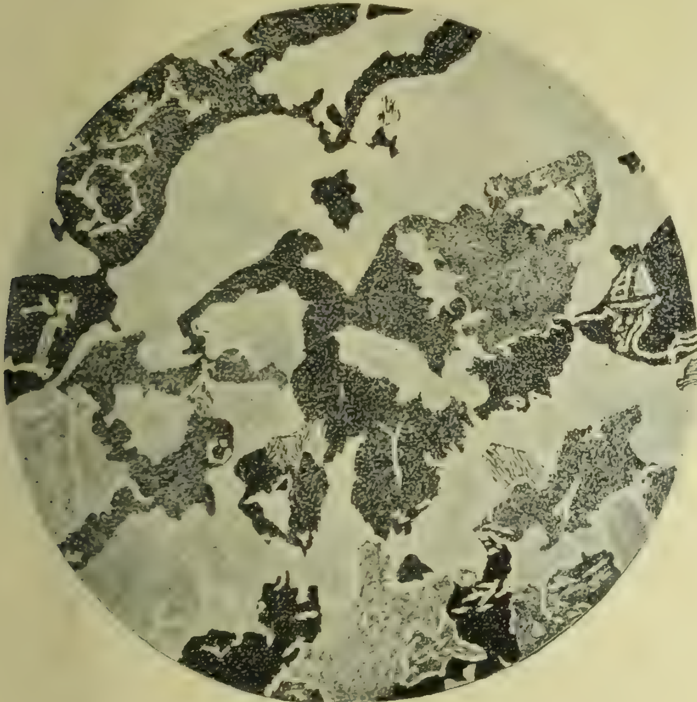


FIG. 3.—Carbon 0·60 per Cent.; Vanadium, 0·71 per Cent. Magnified 450 diameters.

usual volumetric process, using a standard solution of potassium dichromate for the titration. The very small quantity of vanadium found in the iron solution was determined by the hydrogen peroxide colour test. The results are given in Table II.

A consideration of the results in the foregoing table indicates that in most cases practically the total amount of carbon in the steel is obtained as carbide. The slightly lower results are not due to any appreciable decomposition of the carbide during the electrolytic run, but are accounted for by a slight roughness of the bars which prevented the last traces of carbide being obtained.

The results given in Table II. also show that vanadium replaces iron in the carbide, even when the steel contains only such a small quantity as 0·71 per cent. of vanadium, with the formation of a mechanical mixture of the carbides of iron and vanadium corresponding to the formula $11Fe_3C + V_4C_3$.

As the vanadium in the steel increases, more vanadium is found in the carbide, and with the next member of the series, containing 2·32 per cent. of vanadium, the carbide is represented by the formula $2Fe_3C + V_4C_3$.

Coming to the remaining three steels of the series, with 5·84, 10·30, and 13·45 per cent. of vanadium, in each case practically the whole of the iron has been replaced by vanadium, and most probably a definite carbide of vanadium is obtained, corresponding to the formula V_4C_3.*

These results are shown more clearly in Figs. 1 and 2. It will also be noticed (Table II.) that it is possible to reduce still further this small quantity of iron found with the vanadium by digesting the carbide residues with hot dilute sulphuric acid.

Turning Characteristics of the Alloys.—The report of Mr. J. Harrison, Laboratory Engineer in the Metallurgical Department of Sheffield University, on the behaviour of the bars in the lathe is embodied in the following table, the word tough having reference to the capability of the material to curl off in spirals during the turning operations:—

Steel No. A	Carbon per Cent.	Vanadium per Cent.	Turning report.
1,315	0·60	0·71	Tough.
1,316	0·63	2·32	Tough.
1,309	0·93	5·84	Tough and slightly hard
1,310	1·07	10·30	Tough and slightly hard
1,312	1·10	13·45	Tough and hard

Mechanical Properties. — The static results are embodied in the following table, the test pieces being 2in. parallel and 0·564in. diam.:—

Table of Tensile Tests.

Steel No. A.	Yield point. Tons per square inch.	Max. stress. Tons per square inch.	Elongation per Cent.	Reduction of Area per cent.
1,315	12·0	35·9	22·0	41·4
1,316	14·0	35·0	24·5	52·0
1,309	17·0	33·4	25·0	53·2
1,310	15·0	33·7	23·0	31·5
1,312	18·0	37·0	10·0	9·7

Since 1309 contains 0·93 per cent. of carbon, its test result is remarkable.

Alternating Stress Tests.—The dynamic tests obtained under standard conditions on the Arnold machine are tabulated as follows:—

Table of Alternating Tests.

Steel No. A	Alternations endured.		
	1st Test	2nd Test	Mean
1,315	126	112	119
1,316	162	220	191
1,309	144	126	135
1,310	94	144	119
1,312	8	22	15

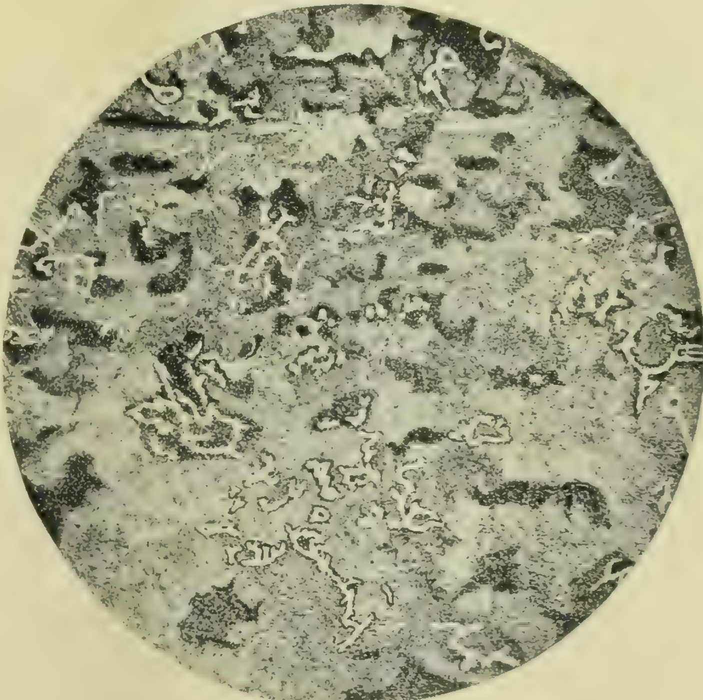


FIG. 4.—Carbon, 0·63 per Cent.; Vanadium, 2·32 per Cent. Magnified 450 diameters.

The poor dynamic properties of the series exemplify the evil influence of drastic annealing on vanadium steels.

Micrographic Analysis. — The microscopical examination of the steels leads the authors to announce provisionally the discovery of two new constituents—(1) Vanadium pearlite; (2) vanadium cementite, V_4C_3.

* It is theoretically possible that this may be a mixture of vanadium carbides.

(1) *Vanadium Pearlite.* This constituent seems incapable of segregating into the laminated variety, and presents itself only in the troostitic and sorbitic forms. Its saturation point seems considerably higher than that of iron pearlite, but this point requires further research.

(2) *Vanadium Cementite.*—This constituent (a decomposition product of vanadium pearlite) is not nearly so mobile

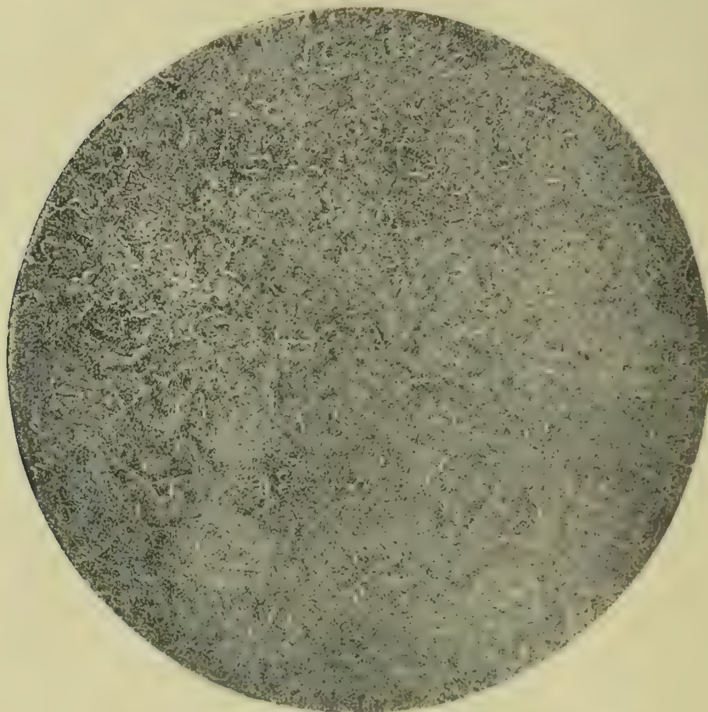


FIG. 5.—Carbon, 0·93 per Cent.; Vanadium, 5·84 per Cent. Magnified 450 diameters.

as Fe_3C, and consequently segregates into relatively minute irregular masses very much smaller than massive iron cementite.

The micrographic analysis has proved—almost beyond doubt—that there is no double carbide of iron and vanadium, since when Fe_3C and V_4C_3 are together in a well-annealed steel the former has segregated as usual, whilst the latter has remained distributed in its pearlite in the troostitic or sorbitic form.

Micrograph Fig. 3.—In this structure was found (*a*) a pale ground-mass of slightly vanadiferous ferrite; (*b*) a few areas of laminated iron pearlite; (*c*) the Fe_3C of decomposed laminated iron pearlite in the form of cell walls and irregular masses; (*d*) dark etching troostitic vanadium pearlite; (*e*) less-dark etching areas of sorbitic vanadium pearlite. This section contains 0·6 per cent. of carbon and 0·71 per cent. of vanadium.

Micrograph Fig. 4.—This steel presents a very confused structure in which vanadiferous ferrite and vanadium pearlite in both the troostitic and sorbitic forms have segregated very imperfectly in spite of the 12 hours' cooling. The only well-defined constituent is the iron cementite which has readily segregated in meshes and masses, but is distinctly less in quantity than that in micrograph Fig. 3. The steel represented in micrograph Fig. 4 contains 0·63 per cent. carbon and 2·32 per cent. vanadium.

Micrograph Fig. 5.—This section consists largely of sorbitic vanadium pearlite, overlaid, however, by irregular meshes, apparently of vanadiferous ferrite. In other words, the steel is not saturated. It contains 0·93 per cent. carbon, and 5·84 per cent. vanadium.

Micrograph Fig. 6.—This contains 1·10 per cent. carbon, and 13·45 per cent. vanadium. It is almost identical in structure with steel No. 1,310, which contains 1·07 per cent. carbon and 10·30 per cent. vanadium. The ground-mass is vanadiferous ferrite, over which are scattered small segregated irregular masses of vanadium cementite, V_4C_3. Each particle is environed by a somewhat dark border of probably sorbitic vanadium pearlite, and small patches and streaks of this constituent are also scattered over the field. The mobility or segregative capacity of V_4C_3 obviously increases with the percentage of vanadium present in the ferrite.

In conclusion, the authors have to tender their thanks to Mr. F. K. Knowles, B.Met., Senior Lecturer in Metallurgy at the University of Sheffield, for much valuable help in making the steels and mechanical tests; also to Mr. Duncan Maxfield, Associate in Metallurgy of Sheffield University, for the patience and accuracy of his work connected with the chemical branch of the research. Finally, the authors have to thank Mr. E. Colver-Glauert, Research Assistant in the University of Sheffield, for his exquisite micrometric reproductions of the four typical micrographs illustrating this paper.*

The authors hope at no distant date to report to the Institute on the chemical and mechanical relations of iron, carbon, and nickel. In view of a suggestion made at the last May meeting of the Institute by their friend, Dr. Stead, the authors wish to state that the absorption and recalescence curves of the steels dealt with in all their carbide researches will be included in a special paper as soon as possible after the unique recalescence laboratory now being fitted up for the Sheffield University by the Cambridge Scientific Instrument Company is available for work.

APPENDIX.

Since writing this paper, the authors, during recalescence observations, have provisionally to announce a discovery of far-reaching theoretical importance.

Steel No. 1,316.—*Carbon*, 0·63 *per cent.; Vanadium*, 2·32 *per cent.*

Cooled from 1,020° C., this steel did not present the point Ar3. Ar2 appeared at 791° C. and Ar1 at 720° C. This latter point was very small for a 0·63 per cent. carbon steel.

Steel No. 1,310.—*Carbon*, 1·07 *per cent.; Vanadium*, 10·3 *per cent.*

Cooled from 1,210° C., this steel failed to present the point Ar3. Ar2 presented the top peak at 830° C. and the lower

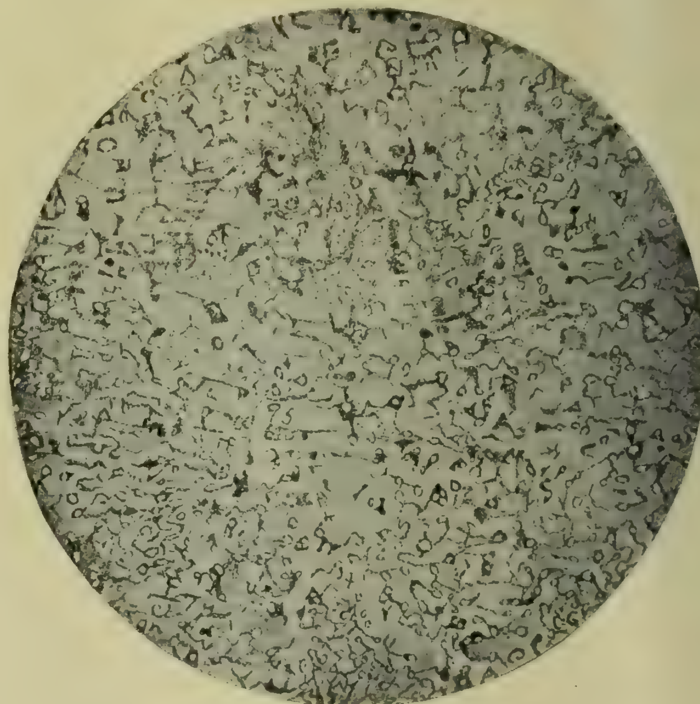


FIG. 6.—Carbon, 1·10 per Cent.; Vanadium, 13·45 per Cent. Magnified 450 diameters.

peak at 816° C. Ar1 was quite absent. On heating, the maximum absorption at Ac2 was at 826° C. Ac1 was absent.

QUENCHING EXPERIMENTS.

Samples of steel No. 1,310, carbon 1·07 per cent., vanadium 10·3 per cent., were rapidly quenched from the following temperatures: 850° C., 1,000° C., and 1,050° C. All after

* The term "sorbitic," as used in this paper, has reference to pearlite in which the carbide, although in a fine state of division, is nevertheless within the range of microscopic vision.

The term "troostitic" has reference to pearlite in which the carbide is in a state of division so fine as to be beyond the range of microscopic vision.

quenching were quite soft to the file. The authors provisionally draw the following conclusions: —

(a) That the point Ar1, marking the formation of vanadium pearlite from vanadium hardenite, must be between 1,200° C. and 1,400° C. (the latter being about the solidification point of the steel). When quenched in water from about 1,300° C., steel No. 1,310 was quite hard, stripping a new file.

(b) That although the steel be quenched in the beta range of temperature, it is still quite soft.

(c) That the above conclusions, when fully confirmed, will form direct proof of the correctness of the views so long held by Prof. Le Chatelier, Sir Robert Hadfield, Dr. McWilliam, and the authors, that the hardening of steel is brought about by carbon in some form irrespective of the range of temperature.

Further experiments have resulted in the discovery of vanadium hardenite, which is formed near 1,400° C. It resembles iron hardenite but seems as hard as topaz.

The authors have to thank Mr. F. C. Thompson, B.Met., Demonstrator of Metallurgy in Sheffield University, for his services in carrying out the foregoing experiments.

THE PREVENTION OF ELECTRICAL ACCIDENTS.*

BY H. M. GASSMAN.

IT is only too true that "accidents happen in the best regulated families." It is hardly possible to limit them entirely, but they may be greatly reduced by a careful study of the conditions. It is well to know "how to act" after an accident has happened, but it is a greater art to prevent its happening. It is only natural to ask, "Why should we be interested in preventing accidents?" Briefly the answers are: First, every employer realises sooner or later that accidents represent considerable loss in money due to the liability incurred, incapacitating skilled employés and disorganising his business, or arousing antagonistic feeling in the public. Accidents directly affect him commercially, to say nothing of the humane side. It is obvious that if an employé co-operates with him towards reducing accidents he becomes more desirable and more highly valued. Second, from a human point of view an employé owes it to his fellow employés and the public, as well as to himself and those dependent, to prevent accidental death and physical and mental suffering.

To the person of average intelligence, electricity is a rather mysterious thing, and there is a general feeling that everything electrical is dangerous. On the other hand, electrical accidents are often the result of disregarding natural laws applying to electricity and a failure to appreciate the risk involved. It is a well-known fact the world over that when the origin of a fire cannot be positively ascertained it is attributed to the electrical wiring, where such is present. Nevertheless, the fact remains that electrical work must be considered as hazardous. It is, therefore, especially important to safeguard every one concerned against injury. This may be in the mine, overhead, on the highway, in the mill, at the factory, or the shop, in the power house or the home. The importance of this can only be fully appreciated when we recall how little is generally known regarding electricity, that a voltage as low as 50 may prove fatal, and that moving machinery is essential to generate and usually to transform electrical energy. We can see dangerous moving machinery, hear the noise that indicates trouble, feel the heat from hot bodies before we come in contact with them, but we lack an electrical sense to detect the presence of electricity by our physical organism. Within the last decade more or less systematic work has been done in the way of minimising accidents along industrial lines, and some legislation has been enacted in this direction.

The general conditions giving rise to electrical accidents are the same as for all other industrial accidents. Among these might be mentioned the following: Inevitable; lack of skill; carelessness; ignorance; absentmindedness; lack of guards; insufficient illumination; overwork; intoxicants; disregard of rules; lack of inspection; confusion of orders; misunderstanding; clothing; lack of supervision and management; absence of signals; lack of visual danger signs; lack of preparation before starting machinery; cleanliness, orderliness.

* Abstract of presidential address delivered before the Birmingham (Ala.) Association of Electrical Engineers.

Inevitable.—This covers accidents that could not be prevented and for which no one in particular can be held responsible. In general, such accidents never happen twice in the same way, and there is usually a combination of circumstances leading up to the accident which could not possibly have been foreseen. Statistics from Germany show that this class covers 42 per cent. of the accidents, the remaining 58 per cent. being due to negligence of employé or employer.

Lack of Skill.—The same report from Germany shows that 20 per cent. of the industrial accidents which occur are due to lack of skill. It is therefore important that no man be put on a job unless he has had sufficient drilling or experience to make him skilled at the work. This is particularly applicable in electrical work, where men have to be drilled and trained in any particular branch of electrical work on account of the lack of suitable skilled labour.

Carelessness.—It is a well known fact that familiarity breeds carelessness or overconfidence. This is a case of "knowing" and not "acting" accordingly. When carelessness becomes habitual the employé should be transferred to work where there is less or no risk.

Lack of Guards.—Fully eight per cent. of German industrial accidents are due to the absence of guards. The guard may have been provided originally and not replaced by the employé when once removed. Such guards should be used to protect one from coming in contact with moving machinery, getting in the path of moving machinery, and falling into openings such as in the floors of buildings, or from walk-ways, platforms and stairs.

Insufficient Illumination.—It is estimated that 25 per cent. of the industrial accidents are due to insufficient illumination. This is particularly true where workmen pass from daylight to places lighted artificially. The artificial light may be sufficient for those accustomed to it, but the eye does not respond immediately to the change in light when passing from a very bright illumination to a place lighted at low intensity. It is therefore important that lamps be placed along walk-ways and thoroughfares rather than distributed uniformly over the whole floor.

Overwork.—Fatigue leads to carelessness, and long hours without rest are responsible for many accidents. The physical is so closely related to the mental that fatigue of one affects the other.

Disregard of Rules.—This closely borders on carelessness, but differs from it by being a wilful violation of rules, and covers such things as deeds of daring or boasting, unnecessary exposure to danger, of taking short cuts for completing a job, instead of doing it the safest way, or trespassing in forbidden dangerous locations. Rules should not be made unless they will be enforced. They should be put up in such shape and so distributed that there can be no excuse for the employé not being familiar with them.

Lack of Inspection.—Machinery and apparatus deteriorates and gets out of adjustment naturally, and many accidents can be prevented by a rigid, methodical and regular inspection sufficiently frequent to suit the conditions and the apparatus. Whenever unsafe conditions or defects in the machinery or apparatus are discovered the apparatus should not be continued in service, without orders from a superior, until repairs or adjustments can be made.

The following are a few important rules applying to electrical workers; which rules, if observed, will reduce very much the risk of handling circuits of dangerous voltage, or of operating electrical machinery of any kind in any place.

No inspection, repairs or changes of cables, wire or apparatus should be conducted by any one except those authorised.

No temporary work should be permitted unless it is good and safe enough mechanically and electrically to be permanent.

Only skilled and experienced workmen should be employed

on hazardous jobs. Such work must be performed under the direction of a competent man at all times.

When instructions are not complete, or not thoroughly understood, consult your superior and follow his directions.

Do not handle circuits promiscuously and do not get the idea that you are expert at it. Overconfidence breeds carelessness and accidents are the result. Competent men are cautious, only unskilled and inexperienced men take chances.

Avoid working on live circuits except where absolutely necessary, then take all necessary precaution to insulate yourself thoroughly from the ground and the neighbouring wires of opposite polarity, using such means as are provided or as are proper for the risk involved.

Before mounting, examine carefully all poles, brackets, cross arms, &c., to see that they are safe. Do not work on defective poles unless they are properly guyed.

Inspect carefully all guy wires, anchorages, poles, towers and brackets before putting up wire and straining.

Inspect all apparatus and tools used; if same are found defective discard them or have them repaired.

When handling wires of low voltage, such as for telephones and for signals, use the same precautions as in handling other wires with which they may become crossed. It is not safe to depend upon the insulation on the electric wires to protect you against shock. Insulation deteriorates with age and especially when exposed to weather or the action of water in mines.

When working on live circuits use one hand at a time and keep the other behind the back. Shocks from hand to hand are the most dangerous.

Insulation on tools and rubber gloves are good things if they are ample for the voltages to be handled, but they are apt to prove a delusion, as they cannot be depended upon being in good condition and satisfactory for the purpose.

Linemen must always use safety belts when working overhead.

Avoid working on circuits running overhead or on lightning arresters while there is any sign of lightning.

Never depend entirely upon tracing out circuits, rather test them out with lamp, magneto, voltmeter or other means.

When working on a dead circuit that might be made alive, treat it as alive.

Where circuits are controlled only from the power house, written instructions should be given to the man in charge of the power to open and close such switches as control the circuits on which work is to be done. The operator must place a tag on the switch, calling attention to danger of closing same before the work is finished. Before this switch is closed see that everything is in the clear and everybody has been notified to keep away from the circuit.

It is the safest plan to short-circuit the circuit that has been made dead before working on it.

Switches and wires of high voltage should be placed out of ordinary reach. Where this cannot be done they must be properly guarded to prevent persons coming in contact with them.

Apparatus carrying over 250 volts must have its frame or case thoroughly grounded.

All wires must be supported securely on suitable insulators.

Insulated platforms should be installed around apparatus of high voltages that is apt to be touched by the operator or other employés.

Lamps on circuits of 220 volts and higher should not be trimmed without using a suitable insulating platform to stand on.

When working on wires underground, special precautions must be taken on account of the dampness and the fact that grounded circuits are used in such places.

Sir Francis Fox, M.Inst.C.E.—The King has been pleased to confer the honour of knighthood upon Mr. Francis Fox, M.Inst.C.E., in connection with his services in the restoration of the foundations of Winchester Cathedral. Among other engineering works with which Sir Francis has been concerned are the Simplon Tunnel, the Cape to Cairo Railway, the supply of electric power to the Rand mines, the extension of the Great Central Railway to London, and the Charing Cross and Hampstead Tube Railway.

ARC WELDING.*

BY C. B. AUELL.

WELDING through the medium of the electric arc may be accomplished by any of three different processes, named respectively after the inventors, Benardos, Slavianoff, and Zerener. Like oxy-acetylene and oxy-hydrogen welding, all of these are very properly classed as autogenous welding processes, since fusion is accomplished without pressure, simply by allowing the metals to melt, then to mix and unite as they cool. The essential difference between the processes under discussion may be briefly indicated as follows:—

In the Benardos process the arc is drawn between the metal to be welded which forms one terminal of an electric circuit and a carbon electrode which forms the other terminal. In the Slavianoff process the arc is drawn between the metal to be welded which forms one terminal of an electric circuit and a metal electrode which forms the other terminal; and in the Zerener process the arc is drawn between two carbon electrodes, the metal to be welded being placed in contact with the arc.

Benardos Process.—The Benardos process is due to Benardos and Olzewski, to whom a United States patent was granted in 1887. From this date it will be noted that the term of the patent has now expired and anyone is therefore at liberty to make use of it.

Apparatus Required.—A complete outfit for this process of welding includes a suitable source of direct current supply, controlling apparatus for the regulation of current and voltage, carbon electrodes, a suitable enclosure for the work, a protective covering for the operator, fireclay or other material for

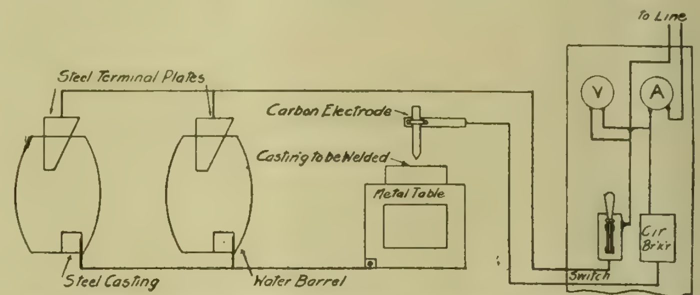


FIG. 1.—DIAGRAMMATIC SKETCH OF ELECTRIC APPARATUS. BENARDOS PROCESS.

moulding purposes, filler and flux. Fig. 1 is a diagrammatic sketch of the electric apparatus as it is perhaps most commonly used. Starting from the generator, one branch of the circuit leads through an ammeter and a circuit breaker direct to the carbon electrode, which usually forms the negative terminal; the other branch of the circuit leads from the generator, through a single-pole switch, to the main rheostat, then to the metal to be welded which, either directly or indirectly through a metal table, forms the other terminal. There are, of course, modifications of this general scheme, each of which possesses one or more features of merit, but the limits of this paper preclude their being discussed in detail.

Current Supply.—The current, which must always be direct, may be obtained in any of several ways: (*a*) from an independent generator, shunt or compound, of at least 15 kw. capacity, preferably larger, at 75 to 100 volts, and either belt or direct driven; (*b*) from public supply mains of like voltage and capacity; (*c*) from a battery operating in conjunction with either (*a*) or (*b*). As intimated, current may also be obtained from a higher voltage than that specified, if it is the only kind at hand, resistance being then introduced into the circuit to cut down the voltage to the required amount. This, of course, is wasteful and is recommended only where the welding to be done is so small in amount or of such infrequent occurrence as not to warrant a proper installation.

Controller Apparatus.—Different current strengths are required for different sizes of welds, and means must accordingly be available for regulating the current supply. This is usually effected by inserting a variable resistance in the main current, though in the case of a suitable generator its field may be weakened instead and the same result accomplished. In the diagrammatic sketch, Fig. 1, the resistance consists of two

* Abstract of paper read before the American Society of Mechanical Engineers.

water barrels arranged in parallel. Pulleys and counterweights are provided by means of which the distance between the terminal plate at the top of each barrel and the steel casting at the bottom may be altered at will and the resistance increased or diminished proportionately. The objection to water barrels is that when the plant is worked hard the water will boil over, thus requiring a stoppage of the work in order to allow the water to cool. The overflowing of the water further causes the hoops on the barrels to rust, which in turn makes necessary the replacing of the barrels from time to time. Again, a spark may occasionally drop into one of the barrels, producing a loud explosion, without damage, however, other than startling the operator. This explosion is due apparently to an accumulation of a small amount of oxygen and hydrogen from the electrical decomposition of the water. For these several reasons it is preferable to use grids instead.

Electrodes.—The type of electrode used is illustrated in Fig. 2. It consists of a piece of pipe threaded as shown, and provided with a wooden handle having an asbestos or fibre guard. Into one end of this handle is inserted and clamped the carbon, which in turn is held by pressure in a suitable metal eyepiece. The carbons as a rule are from ¾in. to 1in. diam. and 6in. in length. They should be hard and solid (uncored), of graphite, not of coke, and in burning away should leave a rounded end instead of a pencil point.

Enclosure for Work and Protective Covering for Operator.—Owing to the intense brightness of the arc the welding must be done in an enclosure, otherwise it would seriously interfere with any other work in the vicinity. It is further necessary to protect the operator thoroughly, as the rays of the arc cause an irritation of the skin much like sunburn, even where the exposure has been of but a few minutes' duration. No more serious consequences ensue, however, and at the expiration of a couple of days all traces of the burn disappear. The clothing is sufficient protection for the body; for the hands and wrists, gauntlet gloves of pigskin, or even of heavy cotton duck will suffice, while for the head a hood made of canvas, wood, or stovepipe, and fitted with a small projecting window of coloured glass, is usually worn. Sometimes the operator prefers to use a wooden shield fitted with coloured glass, which is held in one hand. There is some slight objection to the canvas hood, owing to the lack of ventilation; the stovepipe overcomes this objection, but there is the possibility of receiving an occasional shock in wearing it, due to the carbon electrode being brought accidentally into contact with it. The wooden helmet has neither of these objections, though it is rather an awkward piece of wearing apparel. Any type of headgear has an appreciable advantage over the hand shield, in that both hands are left free. The window should consist of several thicknesses of glass, red and blue, or red and green, the combination being rather more satisfactory than a single colour. The window of the headgear must be made to project an inch or so, for the glass eventually becomes rather hot, and if too

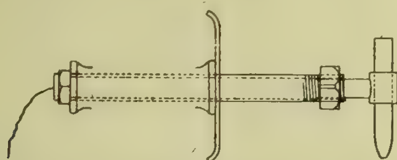


Fig. 2.—Type of Electrode in Benardos Process.

close to the eyes will tend to inflame them. In the operation of welding some fumes are given off, but as these are not sufficient to cause any difficulty no special provision need be made to take care of them.

Filler and Flux.—When welding steel and wrought iron the filler may be soft Norway or Swedish iron, trimmings from boiler plate, bits of broken steel castings, or the like; for cast and malleable iron, besides any of the preceding, it is permissible to use copper wire or rods of special cast iron which is high in silicon. While flux is not necessary, as a rule, in the welding of steel or wrought iron, it is, however, frequently used in connection with cast and malleable iron, and numerous patents have been taken out along this line. A flux considered very good by many practical welders consists of red oxide of iron (Fe_2O_3), 15 to 25 per cent.; borax pulverised ($Na_2Bo_4O_7 + 5H_2O$), 85 to 75 per cent. Another flux consists of oxide of copper (CuO), 5 per cent.; oxide of manganese (MnO_2), 15 per cent.; red oxide of iron (Fe_2O_3), 30 per cent.; borax pulverised ($Na_2Bo_4O_7 + 5H_2O$), 50 per cent. These fluxes may be used either dry or wet. If wet they are shaken directly into the weld a little at a time as it is undergoing formation; if dry, a paste is made and the filler rod coated with it and allowed to dry before using.

Making the Weld.—In making the weld the piece to be welded may be laid upon the metal table, shown diagrammatically in Fig. 1, being thus indirectly connected to one terminal of the conduit, or the terminal may, if preferred, be connected directly to it. The resistance in the circuit must next be adjusted for the proper flow of current. The circuit breaker and finally the single-pole switch are then closed, after which the operator takes the carbon electrode in one hand, and has the filler and flux within convenient reach of the other. The hood or helmet, if a hand shield is not used, is then pulled down over the face, and the arc struck by bringing the electrode into contact with the metal and instantly withdrawing it at least three-quarters of an inch. Many operators prefer a still longer arc, as the heating effect is more regular and better distributed; there is, moreover, less chance of particles of carbon entering the weld and making it hard.

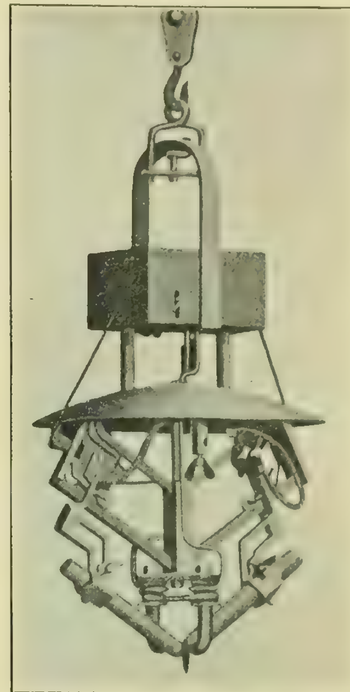


Fig. 3.—Form of Apparatus for Zerener Process.

If the arc is too fierce or if it goes out too frequently the resistance should be increased or decreased accordingly. Assuming, however, a satisfactory condition, the electrode is given a slow rotating motion, thus causing the arc to heat a larger area than otherwise and to assist in a better distribution of the molten metal. A little of the filling material is added from time to time, the arc meanwhile being continued, if possible, without interruption. When the weld is made, and while still hot, it should be thoroughly hammered to eliminate sponginess from the metal, as well as to give it a finer grain. All impurities must be kept from the weld, and the metal should further be perfectly clean before proceeding with the work. This last is accomplished either by chiseling or by tilting the piece to such an angle that when the arc is applied the molten slag will run off by gravity. The piece may then be righted and the welding commenced.

Occasionally it may be necessary, as in the case of certain iron castings, to preheat the piece if cracks are to be avoided. This may be done by means of a gas torch turned directly upon the casting; or a small furnace may be built around the piece by means of firebricks and a gas jet introduced. In the latter case, when the piece reaches a dull red colour, the gas is shut off, several bricks in the vicinity of the proposed weld are removed and the weld made. The bricks are then replaced and the casting allowed to cool off gradually and uniformly.

Other Uses of the Benardos Process.—Besides welding, the Benardos process may be used quite advantageously in other ways, as in the removal of sink-heads from steel castings, the opening of tap holes and tuyeres in furnaces, the boring of holes in iron plates, the cutting up of steel and wrought-iron scrap, &c. From the nature of the work it will be evident that the compilation of reliable data as to current consumption, strengths of welds, costs, &c., is an exceedingly difficult matter. Nevertheless, certain items may be given for those who are interested in the subject, more however as a guide rather than as representing any especially remarkable performances.

Tables I. and II. give the current consumption, &c., for various kinds of work. The greatest criticism which may be made of the use of the Benardos process is that apparently, in

spite of the best care, the results obtained are not always uniform, the welds being occasionally hard. Where, however, no machining enters in, this is not a serious matter; in fact,

TABLE I.—*Benardos Process. Filling Cavity.*

Line Volts.	Arc Volts.	Amperes.	Diameter of Carbon, In.	Length of Arc.
77	43	160	1	¾ to 1
77	42	160	1	¾ to 1
77	45	156	1	¾ to 1

TABLE 2.—*Benardos Process. Cutting Off Cast-steel Sink Head (2⅜in. × 5½in.)*

Line Volts.	Arc Volts.	Amperes.	Diameter of Carbon, In.	Length of Arc, In.	Time Required, Min.
75	47	640	1¼	1½ to 2	4⅕
75	53	560	1¼	1½ to 2	4⅕
75	46	760	1¼	1½ to 2	4⅕
75	52	680	1¼	1½ to 2	4⅕
75	50	650	1¼	1½ to 2	4⅕
75	51	720	1¼	1½ to 2	4⅕

TABLE III.—*Slavianoff Process. Lap Welding $\frac{3}{16}$in. Steel Plates on Edges.*

Line Volts.	Arc Volts.	Amperes.	Diameter of Electrode, In. Iron.	Length of Arc.
50	20	160	¼	⅛ to ¼
50	24	140	¼	⅛ to ¼
50	24	140	¼	⅛ to ¼
50	23	150	¼	⅛ to ¼
51	20	160	¼	⅛ to ¼
51	24	140	¼	⅛ to ¼
58	32	180	¼	⅛ to ¼
58	22	162	¼	⅛ to ¼

TABLE IV.—*Data on Strength of Welds.*

	Breadth, In.	Width, In.	Area, In.	Ultimate Tensile Strength in Tons of 2,240lbs.		Extension in 4in. Per Cent.	Cold Bend, Deg.
				Total.	Per Sq. In.		
Unannealed..	1·0	0·56	0·56	15·3	27·4	12	58
Annealed ...	1·0	0·55	0·55	14·5	26·3	14	160

hardness may prove at times an especially valuable feature, as in the repair of bending rolls. If directions have been carefully followed and hard welds are still obtained, the only solution is either to anneal or to remake them.

Slavianoff Process.—In an endeavour to surmount the difficulty of hard welds, Slavianoff modified the Benardos process by substituting a metal electrode for the carbon, the electrode being usually of the same material as the piece undergoing welding. While in general the process is the same as the Benardos, there are certain details which require close attention. In the welding of iron or steel the electrode should be of the best soft iron wire, ⅛in. to ¼in. diam. by about 12in. in length, and the current approximately 125 to 175 amperes at 25 to 30 volts across the arc; the arc itself will not as a rule be over ⅛in. or $\frac{3}{16}$in. in length, instead of 1in. or so, as in the Benardos process. Of course, these items will vary within certain limits from the figures given, depending upon the size of the work, which must be carefully studied. A considerable amount of skill is required in the manipulation of the electrode, because of a tendency to stick to the metal when contact is made as the arc is struck. The temperature of the electrode and of the piece in the vicinity of the weld should, if possible, be the same; in other words, both should be melted in order to make a true weld. It is perhaps more frequently the custom to make the metal electrode the positive terminal, while in the Benardos process the reverse is usually true. Certain data as to current, &c., are given in Table III.

The Slavianoff process is used for all welding where strength is of prime importance, and is in such cases much to be preferred to the Benardos process. It will, of course, be evident from the details given that the volume of work will be considerably less in the same period of time. Regarding the strengths of welds made by this process, Mr. H. Ruck-Keene, in a paper read before the Institute of Marine Engineers, gives the data shown in Table IV.

Zerener Process.—This process is only used to a limited extent. Fig. 3, taken from Glaser's Annalen, 1907, illustrates one form of the apparatus, which resembles in some respects certain types of arc lamps. The arc is drawn between two inclined carbons and is directed downwards into a pencil point by means of an electromagnet, the piece to be welded being brought under the influence of the flame and thus raised to the required temperature. The construction of the apparatus and the difficulty of obtaining close regulation of the arc would seem to preclude the use of this process to any large extent.

Conclusion. — Arc welding by the Benardos process covers a field entirely its own which cannot be infringed upon with advantage by any other process. It is unequalled both in cost and speed for large work of the rougher kind and where appearance or finish and strength are not of paramount importance. Where the last item is an essential, the Slavianoff process is to be preferred. Compared with welding either by oxy-acetylene or by oxy-hydrogen, it is the opinion of the writer that both of these gas processes have the advantage over the electric arc processes in the matter of average strength of welds, as well as in smoothness of finish; but as regards cost and speed the advantage, as stated above, would seem to be the other way.

GAS PRODUCER FOR LOW-GRADE FUELS.

WE illustrate herewith a construction of gas producer, the invention of E. Ragot, of rue de la Gare, Bettain Court (Haute Marne), France, and P. Pierre-Hervotte, which has been designed for use with low-grade fuel, such as sawdust, wood waste, charcoal dust, and coke dust. The walls of the producer are of fireproof material and are surrounded by a metal envelope. The producer is mounted on a water cistern A and supports at the top another water cistern B for supplying the water injected along with the blast into the producer when utilising certain fuels. The producer also supports a charging platform of the usual construction. The inside of the gas producer has the form shown, that is, of four superposed conical sections united at their bases, the small upper base forming the charging opening being normally closed by a cover. At the small lower base is fitted a perforated cylindrical member C supporting the grate bars. This grate is in three pieces (Fig. 2), the centre part being capable of sliding to permit of cleaning. This formation of the inside of the producer gives rise to two combustion zones at D and E, and provides a double inverted combustion when the lower combustion zone E is the seat of the more intense heating. The upper zone is fed with air by four supply openings F arranged 90° apart, one of which G is of larger diameter than the others and gives access to the interior of the producer.

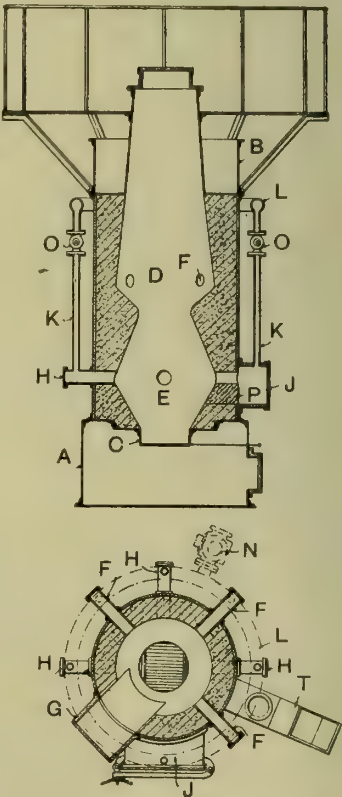


FIG. 1.—GAS PRODUCER FOR LOW-GRADE FUELS.

The lower zone is fed with air by four other similar openings H displayed by 45° with respect to the upper openings. The opening J is larger in size than the others and is closed by a door, which facilitates the breaking up of the fuel when necessary in the lower zone of the producer. A removable fireproof block P is provided which is taken out to facilitate access to the lower zone. All the openings F and H are connected by vertical pipes K with a common annular receiver L arranged

near the top of the producer and obtaining its supply at N in any suitable manner. Valves O enable the air injected into the different parts of the producer to be regulated at will. The lower zone E of the producer is located immediately above the water filling the cistern A, which would rise above the grate bars were it not prevented from doing so by the pressure of the air. This system at one part of its periphery is provided with an outlet tank T (Figs. 1 and 2) comprising a pipe connection R for the outlet of the gas which proceeds first to a washing device and then to a purifier. A vertical partition projecting into the water normally prevents the gas from flowing out through the open duct S at the top of the tank. The object of this duct is to enable the gas to escape in case of an accumulation of gas caused by a stoppage or other reason, this arrangement thus avoiding explosions.

The producer having been charged with fuel and the bellows started, the gases generated move downwards through the fuel and first arrive at the upper zone where a first combustion takes place; continuing their descent they pass

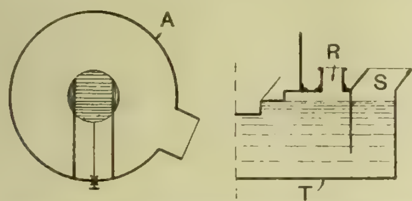


FIG. 2.—GAS PRODUCER FOR LOW-GRADE FUELS.

through the incandescent mass at the lower zone E, where the temperature is higher, and the heavier materials, oils, tars, and the like entrained by the gases are finally volatilised and completely burned. Owing to this double inverted combustion the gases arriving at the water cistern A are thus comparatively pure and all materials capable of caking and obstructing the grate bars and other parts of the grate are burnt. Should, however, caking occur and a breaking up of the fuel be necessary, this can be very easily effected without a prolonged stoppage of the operation of the producer. It is only necessary after having stopped the air injection, to remove the block P and introduce through the door of the passage J iron rods adapted to support the charge of fuel inside the producer. The moving part of the grate bars is then drawn out so as to allow the fuel in the lower zone to fall into the cistern A whereupon the wall of this zone is easily cleaned. The producer is started again without difficulty. The gas on issuing from the lower zone E passes through the perforations of the plate C and the grate bars and comes in contact with the water in the cistern A and bubbles through this water becoming washed and cooled in the process. It escapes into the lateral tank T and the pipe R. The ashes and fine solid particles carried away with the gases are thus retained in the water and prevented from clogging the exhaust pipes. Pipes not shown enable the air injected to be mixed with a suitable quantity of water from the upper tank B.

Additional Inspectors of Mines.—The Home Secretary wishes it to be known that he is now prepared to consider applications in connection with the appointment of 15 sub-inspectors of mines and quarries. Each sub-inspector will be appointed for and attached to one of the six divisions into which the United Kingdom will be ultimately divided for the purpose of inspection. The salary of sub-inspectors is £150, rising by £5 a year to £200 a year. The appointment will be by limited competition. Nominations are given only by the Home Secretary on the advice of the Board for Mining Examinations, who will consider all applications impartially on their merits. No recommendations or testimonials are considered unless based on personal knowledge of the candidate's character and attainments. Candidates are, therefore, particularly advised in their own interest not to seek political or social influence, which will prejudice rather than assist the candidature. The prescribed age for candidates at the time of examination is between 30 and 40 years, and no exception can be made to this rule. Applications for nomination must be made before August 15th next.

RECENT ADVANCES IN BATTLE-SHIP DESIGN.*

BY NAVAL CONSTRUCTOR D. W. TAYLOR, U.S.N.

(*Concluded from page 71.*)

THE question of the proper speed for a battle-ship is one concerning which designers differ more, perhaps, in theory than in practice. Italy is the only nation which has consistently for many years attached great value to high-speed battle-ships. With the exception of Italy, we may almost say that the standard battle-ship speed at the time of the Dreadnought design was about 19 knots; the great majority of battle ships were designed for that speed within half a knot above or below. The designed speed of the Dreadnought class was 21 knots, and most of the nations in their latest ships aim at battle-ship speeds above 20 knots.

The maximum speed of a battle-ship is, in the public eye and in tables of data, a constant quantity. We find it always stated as the maximum speed attained or alleged to be attained on trial. As a matter of fact, there is no characteristic of the battle-ship so variable and indefinite as the actual maximum speed which it can show at any given time. The wind and the sea will materially affect speed, their influence, of course, being transitory. Foulness of bottom due to the length of time out of dock may readily reduce the maximum speed two knots or so below what might be otherwise attained. The condition of the machinery, the efficiency of personnel, the chapter of accidents all affect speed and render it variable and uncertain.

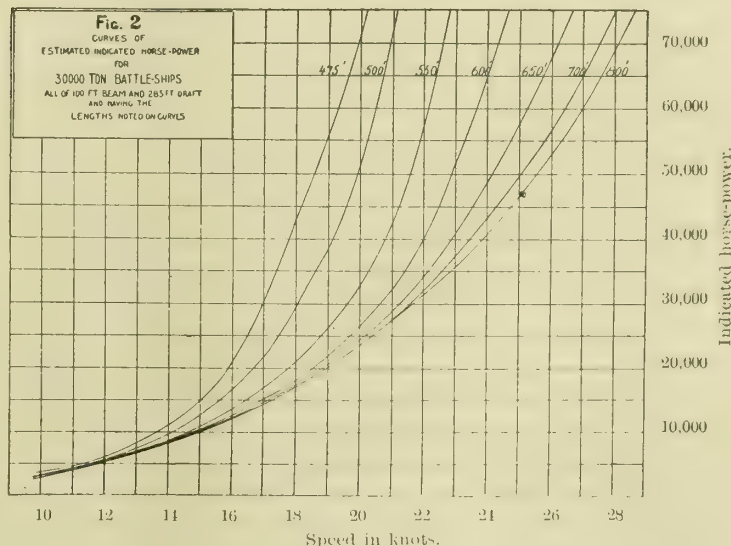


FIG. 2.

The possible speed of a fleet is, of course, the maximum speed of the slowest vessel in it, and hence the speed of a fleet is apt to be very much less than the maximum on trial of any individual member of the fleet, since a large fleet is almost certain to have one or more lame ducks. To the popular mind speed seems to appeal in a peculiar fashion. Superiority of speed seems to imply somehow superior fighting qualities, just as quickness in a pugilist is associated with fighting ability. As a matter of fact, speed appears to be of more value strategically—that is to say, during the moves previous to actual contact—than tactically—that is to say, during actual battle. A number of years ago investigations at the United States Naval War College led our experts to the conclusion that, as regards battle-ships, superior speed was not of great advantage for the probable conditions of actual battle unless superiority was very marked, say three or four knots.

In those days, moreover, the probable fighting ranges in battle were taken to be 2,000 yards or so. The fighting range has now grown to 10,000 yards or more. Bearing this in mind, it is obvious that the relative superiority given by three or four knots advantage of speed when fighting at 2,000 yards would require an advantage of probably 8 to 12 knots when fighting at 10,000 yards. Without pursuing this line further, I think it may be safely stated that for battle-ships the main advantage of speed is the ability it confers to refuse action, which is a polite expression for running away. The next

* Abstract of paper presented at a meeting of the Franklin Institute, February 21st, 1912.

advantage of speed is the ability it confers to force action, or to catch an enemy who is running away. Once battle is joined battle-ship speed is of comparatively minor value.

The penalties of speed, or the sacrifices which must be made to attain speed, are very large indeed. One might think, at first sight, that it would simply be a question of giving up so much weight of armour or armament and putting it into machinery. This, however, is very far from being the case. The indirect sacrifice, particularly as regards protection, necessary to obtain speed is much greater than the direct sacrifice. This is mainly because high speed is necessarily associated with great length. This fact is illustrated by Fig. 2, which shows the estimated curves of horse-power for a series of 30,000-ton battle-ships, all of the same beam—100ft.—with the same draught—28½ft. The influence of length upon speed, sometimes enormous and always important, is obvious from the diagram.

If we assume that in each case we could put a maximum of 70,000 h.p. into the vessel, which is somewhere near the truth, we see that if she were made 500ft. long the speed would be 21 knots, whereas if she were made 800ft. long the speed would be 28 knots. It is doubtful if sufficient length and space could be given to machinery in a 500ft. vessel to enable 70,000 h.p. to be developed; probably it would not be possible to drive such a vessel over 20 knots, owing to limitation of space for machinery.

However, assuming, for the present, that we could get 70,000 h.p. into each vessel, the weight of machinery would be approximately the same, regardless of the length of the vessel; but to build a 30,000-ton vessel 800ft. long would take a very much greater weight of hull than to build a 30,000-ton vessel 500ft. long. This additional weight of hull would have to come from the armour or armament, the 30,000 tons of displacement being fixed. Moreover, the thickness of armour protection for a given weight which could be placed on an 800ft. vessel would be very much less than for the same weight applied to a 500ft. vessel.

It is evident, then, that the penalty paid for speed besides the direct weight necessary to provide for machinery is the additional weight of hull necessary to provide a vessel of the length and form to enable it to be driven at the higher speed, and, superposed upon this, the diminution of the armour thickness, or the restriction of the proportion of the area of the ship protected by armour resulting from the greater length to be protected. The solution of the problem of speed is then obviously a compromise between conflicting considerations, as is the case of so many other problems of warship design. For the latest United States battle-ships the designed speeds have varied from 20½ knots to 21 knots, trial speeds usually being a little better by half a knot or so. It will be seen from Table II. that these speeds are close to the average of those chosen by foreign nations.

The question of endurance of vessels of war, or the distance which they can steam with designed fuel capacity, is one which is very difficult to reduce to absolute rule. In the first place, a battle-ship will seldom make the same run twice with the same coal consumption. There are too many variable factors; the skill of personnel, condition of machinery, condition of bottom, and weather conditions are all variables which enter into the question of endurance. There is hardly any quantity, moreover, which is so apt to be misrepresented as that of endurance and so constantly exaggerated. A trial is made under most favourable conditions, the coal consumption being reduced to the minimum, and the endurance is stated to be that obtained by dividing the coal capacity by the consumption of the main engines, the trial being perhaps of a few hours' duration only. With such methods it is easy to obtain an endurance 50 or 100 per cent. greater than will be shown by the vessels in actual service under average conditions.

The matter of endurance has been brought more prominently to the front during the last few years by reason of the almost universal adoption of turbines for the propelling machinery of battle-ships. These have the unfortunate feature that if designed to give the best speed or the best results at or near the top speed, while giving better results for these conditions than reciprocating engines, they are very much less efficient than the reciprocating engines at ordinary cruising speeds. Now if the greatest endurance is aimed at, it is necessary to steam at quite a low speed, below 10 knots, in fact, but ordinarily endurances are figured on the basis of a 10-knot speed.

The net work done in driving a ship over a distance is proportional to the resistance and to the distance over which the resistance is overcome. For a constant distance the net work is proportional to the resistance, and if the resistance decreases indefinitely with speed the net work will also so decrease. But with any type of machinery the ratio between the net and gross work will decrease at low speeds as the speed decreases, so there will be some low speed at which the gross work done in steaming a given distance will be a minimum. In practice the speed for minimum gross work or maximum endurance is inconveniently small, but in most cases the endurance at the convenient speed of 10 knots is almost as great as the maximum possible endurance.

The reduced economy of the turbines is associated not only with the economy of the turbine proper, but with the reduced efficiency of the type of propeller, which must be adopted to give the best all-round results for the turbine, hence the only fair basis of comparison is one involving all of the factors. I have attempted to make such a comparison between the scouts "Birmingham," "Chester," and "Salem," tried two or three years ago. The "Birmingham" was fitted with reciprocating engines, and the "Chester" and "Salem" with turbine engines of different types. The curves of Fig. 3 show the pounds of water used by the main turbines per knot for various speeds. The "Chester," being fitted with various combinations, required three curves. The basis of pounds of water used per knot was adopted in order to eliminate as nearly as possible the effect of type of boiler, efficiency of firing, &c.

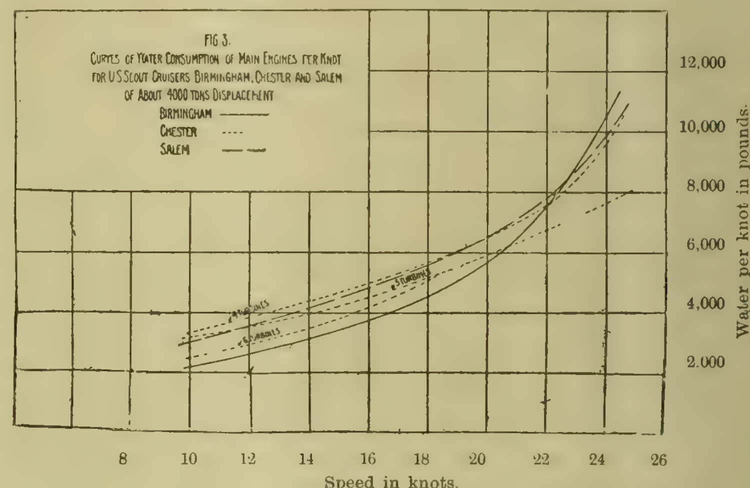


FIG. 3.

I will invite attention to two facts brought out by Fig. 3. In the first place, the curves are still falling off at the speed of 10 knots, so that if these vessels were to steam the maximum possible distance, time being not important, it would be policy, as already indicated, to adopt a speed even below 10 knots. In the second place, the "Birmingham," with reciprocating engines, shows markedly better economy at the low speeds and worse at the high speeds. Incidentally it may be remarked that the maximum trial speed of the "Birmingham" was materially below that of the two turbine vessels.

Although turbines have been adopted by practically all nations, including ourselves, for battle-ships, the superior economy of the reciprocating engines at cruising speeds caused us to return to them for the "Texas" and "New York," now under construction, and contracted for a little over a year ago. Of our two battle-ships just contracted for, the "Nevada" and "Oklahoma," one will have reciprocating engines and the other turbines arranged so as to promise better economy than hitherto.

Many devices have been proposed for obtaining the advantages of the turbines at high speeds and good economy at low speeds. To gain the maximum steam economy for the turbine it should revolve much faster at high speeds than has been the practice, while the propeller of maximum economy should revolve much more slowly. When directly connected each hampers the other.

Among the methods to increase the economy of turbine-driven ships, I may note the following:—

(1) Gearing the turbine shaft to the propeller shaft. Then the turbine can run as fast as desired and the propeller shaft as slowly as desired within the limitations of the gearing. This

method has been used abroad on merchant vessels with claims of success, and is being tried on a United States collier.

(2) Indirect electrical drive—turbine of maximum economy driving electric generators, which in turn drive electric motors on the shafts. This method is being tried on a United States collier under construction. It is heavier and more complicated than the simple gearing, but is more flexible than the gearing method and can be used for powers larger than would be undertaken with gearing at present.

(3) Small reciprocating engines, to be clutched in at cruising speed and thrown out at high speeds, which exhaust to the turbines. This method is being tried on a United States torpedo-boat destroyer under construction, and shore tests of the apparatus indicate marked gain in economy.

As might be expected, each method tried has difficulties and objections peculiar to it, but steady progress is being made, and probably it will not be long before a satisfactory solution will be evolved. It appears to me that at present for vessels carrying the whole or a large proportion of their fuel supply in the form of oil, as do our most recent battle-ships, the ideal solution would be to fit Diesel engines, or the equivalent, driving generators, which in turn drive motors upon the shafts; this installation, however, to be of low power, adapted to drive the ship about 10 knots only. For higher speeds turbines and boilers would be relied upon. Such an arrangement would be slightly heavy as regards weight, but would have the advantage that the endurance would be doubled at cruising speed and an entirely independent means of propulsion would be provided, giving reasonable insurance against breakdowns. It would also be a step towards the generally anticipated use of the oil engine only for propulsion. Such an installation would involve some difficult engineering problems, but I know of no reason why they could not be satisfactorily solved.

Let us now consider briefly the question of the protection of battle-ships. In this connection we need to consider attack by gun fire, by torpedoes, by mines, and by explosives dropped from aeroplanes. The principal things to be protected are the buoyancy of the battle-ship, her stability, her vitals below water, such as engines, boilers, steampipes, magazines, and steering gear; her armament; and the personnel directing the operation of the vessel.

TABLE II.—*Designed Speeds and Armour Thickness of Recent Battle-ships of Various Nations. (From Jane's Warships.)*

Nations.	Vessels.	No. in class.	Year of laying down first of class.	Designed speed, knots.	Thickness of armour belt, maximum.
					Inches.
Great Britain	"Monarch" Class ...	5	1910	21	12
	"Orion" Class.........	3	1909	21	12
	"Colossus" Class ...	2	1909	21	12
	"St. Vincent" Class	3	1907	21	$9\frac{3}{4}$
Germany ...	"Kaiser" Class	8	1909	20	$11\frac{3}{4}$
	"Thüringen" Class	4	1908	20	$10\frac{3}{4}$
	"Nassau" Class	4	1906	19·5	$9\frac{3}{4}$
United States	"New York" Class...	2	1911	21	12
	"Arkansas" Class ...	2	1910	20·5	11
	"Utah" Class.........	2	1909	20·75	11
Japan	"Kawachi" Class ...	2	1909	20	12
	"Aki" Class............	1	1905	20·5	9
	"Satsuma" Class ...	1	1905	20	9
France	"Jean Burt" Class...	6	1910	21	$10\frac{3}{4}$
	"Danton" Class......	6	1907	19·4	10
Italy	"Conte di Cavour" Cl	3	1910	22·5	—
	"Dante Alighieri" Cl	1	1909	23	—
Austria	"Tegetthof" Class...	4	1910	21	11
	"Radetzky" Class...	3	1907	20	9
Russia	"Gangoot" Class ...	4	1909	23	11
	"Imperator" Class	2	1903	18	$8\frac{1}{2}$

As regards gun fire, we rely for protection almost entirely upon armour, whether vertical armour on the sides or horizontal or sloping armour in the shape of a protective deck. It is evident that if the ship were composed of a very large number of small water-tight compartments it would take a number of shots to destroy her buoyancy and stability, since each shot would reach but a limited number of the compartments. This principle of subdivision is relied upon to some small extent for protection against gun fire, but, as already stated, our main protection must be armour.

An ideal system of protection against gun fire would be one where the sides are covered with impenetrable armour from a point below the water line, as low as will ever be attacked by shell, to a point sufficiently high above the water line to ensure that the ship would always retain her buoyancy and stability. If, at this upper level, there were worked a level impenetrable deck we would have protection of buoyancy, stability, and vitals. To complete this conception we should have, rising from this upper level, impenetrable armour superstructures carrying impenetrable turrets, impenetrable conning towers, &c. Needless to say, this ideal is not attained in practice. The demand for offensive power and speed in battle-ships is so great that defensive power in many cases falls far short of the ideal and in no case actually reaches it.

Full information as to actual armour protection of the battle-ships of the various nations is very difficult to obtain. Half a dozen battle-ships of the same size, carrying the same total weight or armour, would distribute it somewhat differently. However, as a rough gauge of armour protection we may use the maximum thickness of the main belt. This is given in Table II. for a number of the most recent ships of various nations, the latest ship in each case coming first.

It will be observed that there is a tendency in nearly every nation to increase armour protection, judging by the maximum side armour thickness given. Another fact noticeable from the table is the comparatively close agreement of a number of nations in the maximum side-armour thickness of their most recent ships. This is 12in. in Great Britain, Japan, and the United States, $11\frac{3}{4}$in. in Germany, 11in. in Austria and Russia, and $10\frac{3}{4}$in. in France. There is no information as to the Italian ships, but, considering their speed, it is not likely that their armour is very heavy.

For many years there have been two opposing classes of thought as regards armour protection. On the one side we find the greatest importance given to the side armour with the idea of keeping the shell out of the ship as long as possible; on the other side we find great importance given to the horizontal armour, or sloping armour, the idea being that the shell would not do much damage provided it does not reach the vitals. Hence, we find material variations in the relative weights devoted to protective decks and side armour.

As illustrating current ideas of armour protection I invite attention to Fig. 4, giving the approximate distribution of armour upon some of the best protected of the most recent battle-ships, namely, the Argentine Republic battle-ships "Rivadavia" and "Moreno," building in American shipyards upon American designs. It is seen that we have first a 12in. belt extending over the midship portion of the vessel and tapering slightly forward and aft until we pass the last heavy gun position, where it drops abruptly to a thickness of 5in. or 6in. Above this belt is a uniform thickness of 9in. of armour extending to the upper deck and protecting the bases of turrets, smokestacks, engine hatches, &c. The barbettes and turrets rise above this level, their protection being about equivalent to that of the main belt. We also have conning towers projecting above this level.

The main protective deck, with a flat portion above the water line and sloping to the bottom of the side belt, is 2in. nickel steel, and at a high level we have also 6in. armour protecting the 12in. to 6in. guns. There are, in addition, a number of 4in. guns mounted without protection on top of turrets and elsewhere. Below water we have a heavy bulkhead worked about 10ft. within the side, intended primarily for protection against torpedoes.

The question of protection against torpedoes is one which is by no means solved. The usual practice has been to make compartments as small and as numerous as possible where torpedo explosions were liable to occur, and the larger the size of ship the less the danger that a single torpedo would put her out of action.

In the war between Japan and Russia there were some very striking examples of the deadly effect of submarine mines carrying large charges of high explosives. During that war the torpedoes did not score many hits, and, when they did score a hit, did not accomplish the damage which had been antici-

pated by torpedo enthusiasts. But since then the speed, accuracy, and weight of explosives carried by torpedoes have all been increased, and there has been developed the torpedo gun, or a torpedo carrying in a "gun" a shell charged with high explosives, which is fired, when the torpedo strikes, with a velocity sufficient to penetrate the ordinary ship through and through. This device will probably be almost as effective against a ship protected with torpedo nets as against one not so protected. The question of further protection against torpedoes has been talked of for years, and there is more and more tendency to fit such protection. It has usually been fitted as upon the "Rivadavia," but there are advocates of fitting it externally in the shape of external armour far down on the ship. There is little reasonable doubt that battle-ships of the near future will carry materially greater protection against torpedoes than those of the recent past.

As regards attack from aeroplanes, which, so far as can be anticipated at present, will come entirely in the form of explosives dropped from the aeroplanes, protection is not yet a difficult matter. Any bomb so dropped cannot be expected to have much penetrative power, and from present aeroplanes must have comparatively small weight. It would be possible to fit nets or light shelters above vital spots which would explode the bomb before it reached a dangerous position. With the rapid development of aeroplanes, however, their attack may become very serious within comparatively few years through increase of carrying capacity.

It will have been observed that in speaking of protection against torpedoes I intimated that present protection was not satisfactory as regards the most recent forms of attacks by this weapon. The situation as regards attack by gun fire is also not satisfactory. It may be readily inferred from the varying thicknesses, &c., of the armour on the "Rivadavia" that the designer had at his disposal an inadequate weight of armour and has to ponder almost ceaselessly as to its distribution, giving, of course, the greater weight where there is the greater danger. He is in the position of the tailor who must cut his coat to suit his cloth, but finds his cloth quite inadequate to make a proper coat of any fashion.

The recent increase in calibre of heavy guns in this country and England has emphasized the fact that the attack by gun fire is markedly ahead of the defence by armour. In "Fighting Ships for 1911," by Jane, the penetration of the new British 13½in. gun in Krupp armour is given as 26in. at 3,000 yards and 22in. at 5,000 yards. While ranges of 3,000 yards and 5,000 yards have become very short for fighting within the last few years, the penetration of this gun at 10,000 yards would probably be 15in. or 16in. of armour, and, except in favourable weather, it would hardly be possible to carry on the fight at greater ranges than 10,000 yards, owing to difficulty of vision.

Bearing in mind that the heaviest armour carried by any British ship mounting 13½in. guns is but 12in., we may say that these ships can penetrate their own sides as far as it is possible to see. The same conclusions will apply to the 14in. gun mounted on the American ships, and, indeed, we may say almost the same thing of the more powerful of the 12in. guns whose use is practically universal.

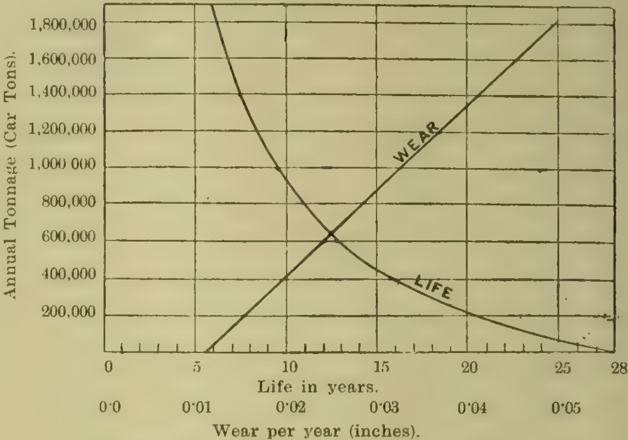
As may be inferred from Table II., there is a tendency to increase armour thickness as the size of ships increases, and in the most recent United States ships this has been carried materially further than indicated in the table; but increases hitherto made can hardly be regarded as adequate, and it must be admitted that at the moment the gun is superior to the armour. Whether the armour will again forge ahead by superior combination of old elements, the development of still further improved armour, or the devotion to armour of a larger proportion of the displacement, it is impossible to say, but there is great need for improvement in protection, and it would seem fairly safe to prophesy that for some years to come we may expect to see the protection developed relatively more rapidly than the attack. I think that is certainly the proper and much-needed line of development.

Fatal Steam Pipe Explosion on an Italian Steamer.—A wireless telegram received at New York says the first engineer, chief fireman, and three stokers were killed by an explosion of a steam pipe on the Italian steamer "Principe di Piemonte," on 17th inst., while several others were injured.

TRAMWAY TRACK MAINTENANCE.*

BY WM. THOM.

In taking track maintenance for the subject of my paper, I feel that I am entering upon one of the most acute and difficult subjects which a tramways manager has to face. It has often occurred to me how useful would be the publication of the actual methods adopted by those responsible for the various undertakings, in order to arrive at a suitable basis for regulating the building up of a renewals fund, and it is mainly with the object of ascertaining other engineers' experiences and theories that I am now putting forward this paper. Of course, some undertakings are in the happy position of having ample funds to deal with renewals as required. In other



CURVE SHOWING LIFE AND WEAR OF RAILS.
"Life" Curve based on 87lb. rail giving $\frac{5}{16}$in. maximum wear.
"Wear" Curve is for rail with Tables 1¾in. to 2in. (87lb. to 100lb.)

cases, however, it is very difficult to make provision out of the year's profits for the liabilities accruing each year, and although it may be that the actual renewal will not fall due for a number of years, it is, I consider, necessary to make adequate provision annually, owing first to the fact that it has become due, and secondly to the often small balance available for this purpose. Repairs, which form no small part of the annual charges, have also to be cared for accordingly. I have found that they vary widely over long periods and are affected by renewals to no inconsiderable extent.

Table of Rail Wear and Life Records.

Route	Car-miles per mile of track per an.	Av. Weight of loaded car	Car-tons per an.	Car-tons to date.	Life in years.		Weight of rail. Lbs. per yd.	Depth of groove. Inches.
					From curve	From gauging		
1	44,310	11·375	504,026	3,028,182	14·1	16·6	87	$\frac{7}{8}$
2	39,940	9·312	371,921	2,603,447	16·4	17·5	87	$\frac{7}{8}$
3	87,982	11·5	1,011,793	8,094,344	9·6	11·4	87	$\frac{7}{8}$
4	58,176	8·5	494,496	3,708,720	14·2	15·4	87	$\frac{7}{8}$
5	120,102	7·5	900,765	8,257,012	10·3	12·0	87	$\frac{7}{8}$
6	89,838	7·5	673,785	5,502,577	12·4	14·7	87	$\frac{7}{8}$
7	56,266	7·75	436,061	3,750,124	15·8	22·2	87	$\frac{7}{8}$
8	44,538	11·437	509,381	4,329,738	14·1	16·4	87	$\frac{7}{8}$
9	68,258	11·5	784,967	5,965,749	11·3	14·5	87	$\frac{7}{8}$
10	79,149	11·562	915,120	3,813,000	10·3	10·5	88½	$\frac{7}{8}$
11	36,274	7·562	274,303	2,240,141	19·0	20·0	87	$\frac{7}{8}$
12	40,880	7·312	298,914	2,092,398	18·1	18·0	87	$\frac{7}{8}$

Analysis of rails showing the extremes of wear found on Route 12. Sample 1: C, 0·50; P, 0·0595; Mn, 0·50; S, 0·22; Si, 0·186; wear in seven years=0·1875in. Sample 2: C, 0·53; P, 0·111; Mn, 0,580; S, 0·041; Si, 0·093; wear in seven years=0·047in.

Analysis of a rail showing the average wear for the whole route. Route 7: C, 0·615; P, 0·030; Mn, 0·570; S, 0·049; Si, 0·093. Route 12: C, 0·42; P, 0·064; Mn, 0·450; S, 0·029; Si, 0·190; wear in seven years=0·125in.

I have followed with much interest the published averages of expenditure of the working results of various systems over a number of years. From these results I have found that at best they can be applicable only as a guide for future years for the systems from which they were immediately derived or of very similar ones. In fact, I have only to turn to the

* Abstract of paper read at the annual congress of the Tramways and Light Railways Association at Swansea. The author is the general manager of the Potteries Electric Traction Company, Ltd.

results on the system with which I am connected to find that the average expenditure on renewals and repairs during the last few years is a very inadequate guide for the next seven years, although most of the track was first laid down something like 11 years ago. Perhaps when half a century has passed over the industry, some average on this basis could possibly be estimated, but even then only if there has been no advancement in constructional details and materials. In every case the diversity in the frequency of services must play a great part, as it may vary as much as from 50 to 100 per cent. on the same system, and the same variation may be found between one system and another, while in the course of, say, 50 years the business over lines where the service is now infrequent may be very much improved. The factor of car-mile run per mile of track should therefore govern the basis for annual charge rather than that of track mile so often applied.

I desire now to emphasize the fact that the greater amount of useful rail life is obtainable when the service is most frequent, and consequently the length of time as well as the mileage affects the ultimate useful life. This brings me to the theory, which I have applied for some years and found satisfactory in working, namely, that of calculating the life of the rails from the car tons or car miles run per track mile (the former preferably), including time as the other factor for loss of life brought about by other agencies than running.

The application of this method of obtaining the life of a particular rail was published in the Association "Journal," of January, 1911. When once adjusted for the particular rail and conditions to which it is to be applied, the system obviates the necessity for gauging year by year every part of a system where different services exist, except only as a check. In order to show more clearly its application, I am submitting, in addition to the curve previously published, a table of figures which should be found sufficiently convincing to prove the utility of the system, notwithstanding that the original records were obtained with rather crude apparatus which can be and has now been improved upon. I am assuming, of course, that gauging is accepted as a reliable means for finding the ultimate rail life. It is, I know, to some extent resorted to, but whether to ascertain the rail life with the object of determining the dates for renewal, I should be interested to hear. Although wear is determinable by actual measurement, the useful life may differ and economy be served by replacement at an earlier stage, owing to crippling through hammered joints or corrugation, or both.

In cases where a perfect track is the first consideration rather than cost, the problem is not a difficult one, but when the rails have still a few years of life remaining, which must be taken advantage of, notwithstanding defective joints (the greatest source of trouble), my experience has been that the full life of the rails can be satisfactorily and economically obtained.

I think that a basis such as I have outlined, with few exceptions, gives the means of estimating comparatively accurately the liabilities of almost any undertaking for many years ahead. Let us consider, therefore, the great advantage it must be to those responsible for the administration of an extensive business, the best results of which are greatly dependent upon a knowledge of future liabilities in respect to track. To the directors of a company perhaps, more than to a local authority, this information is of the utmost importance, as everyone must know, for it enables them to provide in an adequate manner for renewals, whereas, if provision is made only for the immediate future, there may be a tendency to underestimate the position; in fact, great discrepancies may arise during the life of an undertaking in this connection which might hamper its position for many years.

As regards the means taken to eliminate defective joints, their entire removal was resorted to, the bad ends being cut off and the rails closed up, and the results have proved satisfactory, both in respect to running and cost.

As a proof of the advantage which such a repair has on equipments, one has only to observe the action of the motors while passing over the joints in each case; in fact, the attention of anyone conversant with tramway working hardly needs to be called to so self-evident an improvement. The reconstructed joints are very little inferior to new ones, and the permanency of the work is assured so long as the rails are comparatively sound and not too short. When the joints have reached that condition which may be termed bad—I need not, I am sure, give a closer definition—the amount which can be spent in repairing by ordinary means, packing and paving, is considerable. It has to be repeated so constantly, if the track is conscientiously maintained, that in a term of three years, or even less, the cost exceeds the more expensive form of repair just referred to. I would say that the results herein referred to have been obtained over a large extent of track. I am speaking more particularly now in reference to paved track abutting macadam, which is quite another matter from the conditions where the roads are entirely paved.

In regard to the question of rail corrugation, many theories have been advanced as to the cause and means of avoiding this condition. Each theory, no doubt, touches on the salient points, and although there may not be convincing proof as to these theories, a great deal of good has been served by educating our minds to a better understanding of the subject generally. Less, however, has been said of the success attained in the removal of corrugation at a comparatively reasonable cost. I have it on good authority that corrugation is being kept down satisfactorily on some of the larger undertakings of the country; but how many, I would ask, have not so far accepted the position that it is something to be dealt with thoroughly in the ordinary course of maintenance? Until a year or two ago I had not whole-heartedly for one, I will admit, and while I have been dallying with low-priced appliances, which are quite inadequate, I have become more and more imbued with the fact that corrugation must be dealt with adequately in the form of a repair and receive accordingly all due attention in our annual programme, not alone on account of its being the primary cause of much of our track repair bill, but also having in view its effect on rolling stock.

It is a natural conclusion that corrugation can be dealt with most effectively when it first appears, for the deeper it is seated the more difficult and costly becomes its removal. Grinding is so far the only feasible remedy, but to deal adequately with any extent of track, in fact, to make a satisfactory job at all, it requires a machine of the first grade in grinding appliances. A good machine is costly, but the saving in repairs should justify the investment in the case of fairly large systems, while with the smaller undertakings I have no doubt the demand would soon create a business of hiring of suitable machines. In this connection only lately a company has been formed to exploit one of the most comprehensive tools for work of this nature which has yet been invented. The invention, which is both a milling and grinding machine, is capable of removing anything up to ½in. of metal from the bottom of the groove and lip of both rails at the same time, at a rate of from 12in. to 18in. per minute, the rate depending upon the depth of cut and hardness of rail. It is also capable of removing from the head of the rails at the same time sufficient metal to give a perfect surface to eliminate dished joints, if required. Grinding can be done at the rate of about 12ft. of rail per minute, removing the worst corrugations at a cost of about 3d. per foot. A most noteworthy point with regard to the working of the machine is the accuracy which is said to be obtainable, no matter what condition the rails may be in.

Many miles of both railway and tramway track have been treated by this machine abroad in respect to rail-head machining and grinding and groove deepening, and I have no doubt that much good work lies before such appliances in this country, so long as our rail steel can be machined. Our safeguard, however, appears to lie in a direction where the use of even the best tool steel will prove futile. Depth of groove should, I maintain, be entirely a question of rail section in the first instance, but if corrugation cannot be overcome, grinding appliances should still find a field in even the distant future.

At a meeting of the executive of the Scottish Miners' Federation at Glasgow last week reference was made to a new Explosives Order which had been issued by the Home Office, making it compulsory that in blasting in naked-light mines a certain class of fuse with an igniter attached must be used in future. This, it was stated, had created considerable dissatisfacton among Scottish miners, and it was resolved to put the matter before the Home Office with a view to securing exemption from certain clauses of the new Order.

MANUFACTURE AND TREATMENT OF STEEL FOR GUNS.*

BY GENERAL L. CUBILLO.

It is about 30 years since steel was definitely adopted by the chief countries of the world for gun construction. The many difficulties presented in the manufacture of large homogeneous masses of steel, and the resistance offered by tradition and routine to every change in industrial processes, were the chief causes of the continuation of the use of cast and wrought iron, in the third quarter of the last century, if not for the whole construction, at least for the principal elements of guns. The celebrated American artillerist, Rodman, cast large calibre guns, of cast iron exclusively, and applied, during and after the casting process, his invention of cooling the inside of the gun with water, and of heating the outside in such a manner that the inside was compressed by the outside. By this the maximum tangential resistance of a single tube is attained, and it is then best fitted to oppose the pressure of the powder. The metal used by Rodman in the manufacture of guns was of a quality which has not since been surpassed. The pig iron employed was charcoal and cold-blast iron, from ores of the greatest purity, so that the resulting cast iron possessed the best mechanical qualities. The resistance of cast-iron guns was certainly increased by the Rodman process, though it was not known exactly by how much, since it is impossible to apply the rules of shrinkage to guns treated as described. But the improvement so obtained was not sufficient for the requirements of the artillery, and cast iron, whether alone or combined with wrought iron or puddled steel, was incapable of withstanding very great pressure. It was certainly possible to fire the guns so constructed with charges larger than those employed in ordinary cast-iron guns, but the difference was not great, since a very considerable part of the gun was made of cast iron, the mechanical properties of which are deficient as compared with those of wrought iron and steel. In France and Spain a combination of steel, wrought iron, and cast iron was tried, the former metal being employed for that part of the bore where the pressure is greatest, but this combination, which actually produced guns more powerful than those made of cast and wrought iron, was abandoned since, owing to the progress of metallurgical science, the manufacture of steel in large masses had now become possible. The guns made of this triple combination were capable of withstanding a pressure of 2,200 kg. per square centimetre. It was necessary to use quick-burning powders in them, because, the steel tube not being of the total length of the bore, the gun at the cast-iron end was much weaker and incapable of withstanding great pressure. It is therefore easy to understand why, as soon as it became possible to cast great masses of steel, this metal, with its greatly superior physical and mechanical properties, was exclusively adopted for the construction of large guns. It will always be a distinction, however, for the Krupp works to have been the first to cast great masses of steel, while the Bessemer and open-hearth processes were still unknown to the metallurgists, but the method by which Alfred Krupp achieved his wonderful results is so well known that it need hardly be described here.

Conditions of the Steel Required for Gun Construction.—If it were possible to produce a metal at low cost such that it possessed a high elastic limit, and also high tenacity, great ductility, and resistance to the wear produced by the powder gases at great pressure and high temperature, with, moreover, a very high melting point, such a material would undoubtedly be the most suitable for the manufacture of guns. The very great pressure which the material must withstand is not, it is true, of great duration or of great frequency in large and medium-sized guns; but it is necessary to take into consideration the fact that what causes this enormous pressure is the highly heated gases, which exercise both a physical and, in a certain portion of the bore of the gun, a chemical action on the metal. As has already been said, steel has been adopted as the only material suitable for guns. But steel offers so great a variety of types, that it becomes necessary to select from among these one which possesses in the highest degree the conditions already laid down. If the steel is ordinary carbon steel, its high elastic limit is accompanied by a high tenacity and less ductility than that which accompanies a metal of smaller elastic limit and tenacity. The resistance of the former metal to dynamic stresses will be less than that of the second, and its melting point will also be lower. The gun-makers have universally adopted a metal between the dead-soft and the hard steels, namely, an iron-carbon alloy, tending rather towards mildness, due specially to its high melting point. This last property is now very important, on account of the use of the modern smokeless powders, and especially the nitro-glycerine powders. The high combustion temperature of these powders, and the incomplete obturation of the driving band of the projectile at the commencement of its travel in the bore of the gun, is the origin of what is called erosion in the bore. The modern experiments of Vieille and some others made at South Bethlehem, not to mention the earlier ones made by Sir Andrew Noble, have demonstrated without doubt that the mild steels are better able to withstand the effects of erosion, because, amongst other properties, they possess melting points higher than those of the hard steels.

An ordinary carbon steel for guns has about 0·5 per cent. of carbon, and its place in the iron-carbon solution is in the series of the metals called steels, having a carbon percentage of less than 2 per cent. The characteristic of this series is that it is not eutectic at its freezing point, and that it presents a similar phenomenon in the subsequent cooling, when it arrives at the point Ar in the cooling curve. All this refers only to the ordinary carbon steel. The ternary alloy of iron, carbon and nickel or the quaternary alloy of iron with carbon, chromium, and nickel as employed in the manufacture of medium and small guns only, because the cost of such an alloy would be prohibitive in the construction of the larger ones, especially now that the principle of uniformity of calibre has been adopted by all the navies of the world. It must be said, however, that the A and B tubes for the great 16in. experimental gun manufactured in the United States are of nickel steel. In adopting this alloy for the construction of guns it has been necessary to diminish the percentage of carbon, because if it reached that of ordinary carbon steel with percentages of 2·5 to 3·5 per cent. of nickel the steel would be very hard, that is, it would be what Mr. Guillet calls "martensitic steel."

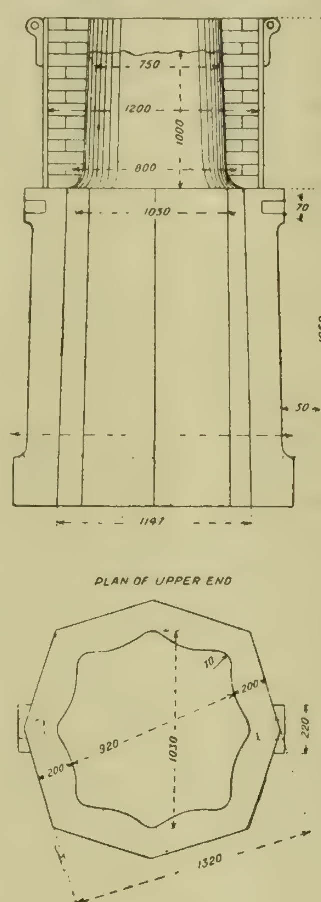


FIG. 1.

Mechanical Tests.—It is not necessary to give here a complete table of the specifications for gun steel as required by the armies and navies of the European and American powers. In all the specifications two different kinds of mechanical tests are required: in the one case, that of continuous and progressive tension up to the yield point, together with the measurement of the elongation after breaking; while the other test consists in subjecting the test-piece to a certain number of impacts according to details and conditions fully specified, or perhaps to some bending test, equally fully specified. If the steel has been manufactured from pure materials, such as the best Swedish pig iron and from scrap from the puddling of the best hæmatite pig iron, and if it has been carefully cast, forged, annealed, hardened, and tempered, the tensile tests are quite sufficient in the author's opinion; while the close examination of the forgings during machining will, conjointly with the tensile tests, also convey a good idea of the quality of the metal, so that the impact or bending tests can be dispensed with. But perhaps it may happen that the heat-treatment has not been properly conducted, and that the metal which withstands the tensile tests may fail in the impact tests. The latter are those which give a really good idea of the brittleness of the metal. Many years ago these mechanical

* Paper read before the Iron and Steel Institute.

and bending tests were introduced into the specifications for ascertaining the presence of phosphorus in the steel. It is possible that a metal with a high percentage of this metalloid may give satisfactory results in the static tensile tests, and that the yield point and the ductility may be very good; but this steel would certainly withstand far fewer impacts than a very pure steel. Indeed the tests which a metal suitable for gun construction must undergo must produce stresses similar to those caused in the gun by the powder gases. This metal, when the gun is composed of a single tube, as is generally the case in mountain guns, passes, in an infinitesimal space of time, from the state of repose to a strain of two-thirds at least of its elastic limit of static tension; and when the gun is a composite tube the concentric layers of some of its elements pass in an equally short space of time from a state of compressive stress to another of tensile stress, both of which are opposite states of stress of considerable importance. Taking into consideration both the opposite stresses to which the elements of the guns are subjected, before and under fire, perhaps the best mechanical test for gun steel would be that of alternating stresses with considerable variation, these stresses being repeated a certain number of times in harmony with the rounds fired by the guns. The shock tests are now universally accepted, as has been said, in order to ascertain the fragility of the metal. The resolutions of the last Congress of "Les Methodes d'Essai des Materials" assembled at Copenhagen recommend a shock test with test-pieces, together with a slight nick in one of the long sides of the piece. Certainly this test must be adopted as one of the means of ascertaining the good quality of gun steel.

Melting of the Steel.—Of all the processes employed in the melting of steel the only ones used in the manufacture of gun steel have been the crucible and the open-hearth processes. The first process was naturally employed before the introduction of the open-hearth method, and for some time afterwards; but the latter has now superseded the crucible process, except at the Krupp works.

Mention has already been made of the great claims possessed by this firm as the pioneers in casting, by the crucible process, great masses of steel intended for gun construction. Credit must also be extended to the English firms of Firth, Vickers, and Whitworth, which also employed their energies in the improvement of this manufacture. The firm of Krupp has always claimed that the crucible process offers the best guarantee for a sound metal for gun construction. Undoubtedly it is possible to obtain by it a metal of great purity with regard to phosphorus and sulphur than by any other process, if the material charged in the crucibles is wrought iron from hæmatite pig iron. The metal obtained in this case will be the best possible steel, and it will not contain occluded gases; or at all events in very small proportion. If the metal charged in the crucibles is free from oxides, the only gases dissolved in the steel will be those which have passed through the walls of the crucibles.

In the author's opinion steel made by the crucible process must lack homogeneity, because it is almost impossible that the composition of the charge of all the crucibles will be the same. It is also impossible to secure uniformity of composition in the ingot mould, bearing in mind segregation. The only way of securing homogeneity by this process would be to teem the crucibles first into a hot ladle, and then into the ingot mould. The principal reason for this lack of homogeneity lies in the impossibility of analysing all the puddled bars which form the charge of the crucibles, classification by the eye being very uncertain. Therefore, in the author's opinion, a massive ingot of steel cast by the crucible process is more heterogeneous than a similar ingot cast by the open-hearth process. The open-hearth acid process is generally employed for the casting of great masses of steel. The basic process can of course be employed, provided the materials charged are acid; and there is no difficulty in obtaining by the open-hearth process, that is, by the dissolution in a cast-iron bath of a certain quantity of wrought iron or steel, a very pure metal, such as is required in the construction of guns. All depends on the purity of the pig iron and scrap charged.

It is the constant practice of all the steel works where steel for gun construction is regularly made to employ Swedish pig iron of the best quality, the phosphorus being as low as 0·025 per cent., and the sulphur lower than this amount; and for the scrap, puddled balls or bars from the best hæmatite pig irons.

By puddling this pig it is possible to obtain a product with phosphorus and sulphur as low as 0·001 per cent., and as furnaces of 50 or 60 tons capacity are now very common, and as for the casting of the largest element of the new great guns it is not necessary to have ingots of more than 100 or 120 tons, the result is that it is not very difficult to obtain a great uniformity of the metal by this process. The conditions of open-hearth working permit of working two or three furnaces so uniformly that, at the time of casting, the metal of the two or three furnaces will be perfectly similar. The steel is much exposed to the oxidation of the furnace gases, always in contact with the bath; and to this action is added that of the iron ore incorporated for oxidising in a rapid and energetic manner the silicon and carbon in excess of that required in the steel. There are many means of diminishing the oxidation of the bath; one of them is to prepare the charge by putting in the furnace the greatest possible amount of scrap, with the smallest quantity of carbon, and conducting the refining process by the furnace gases only without the addition of any iron ore. This particular method of working is extraordinarily slow; first, because, as the materials, both pig iron and slag, are charged at once and cold, the mixed bath is very low in carbon and its melting point very high. It therefore requires more time for melting it than if the charge had been composed of equal parts of pig iron and scrap. Secondly, because the oxidation of the carbon by the gases is not so efficacious as that by the iron ore, this being more in contact with the bath and the former acting only on the surface. Operating in this way the final steel is almost free of oxides, and in order entirely to eliminate them additions are made, at the end, of certain iron alloys, such as ferro-manganese and ferro-silicon, which by their action upon the bath reduce the iron oxides dissolved in it. This addition is the more required when the charge has been of equal parts of pig iron and scrap. The percentage of carbon of such a charge at the fusion or melting time will be very high, and it is not possible to oxidise the excess carbon to the point required in the artillery steel by the action of the gases only, and it is almost imperative to employ the iron ore for accelerating the oxidation of the carbon.

Fusion at Trubia of the Ordinary Carbon Steel for Guns.—The steel works at Trubia comprise two furnaces—one of large capacity, capable of taking charges up to 54 tons, and the other of 16 tons. Therefore it is possible, working with the two furnaces, to obtain an ingot of 64 tons. The furnaces were supplied by Messrs. Frederick Siemens, of London, and are of the usual design. They are situated in a straight line, with a very commodious working platform, and are served by an electric-charging crane, of the well-known Wellman type. For the service of the casting shop there are two overhead electric travelling cranes, one of 75 tons capacity, with one motor only of 30 h.p., and the other is a Niles 50-ton capacity crane, worked by four motors of 130 total horse-power. The second crane, of course, has been more recently installed than the first.

In the fusion of the ordinary carbon steel for guns, the materials employed are Swedish pig iron and puddled ball from Bilbao hæmatite pig iron. In order to convey an idea of the operation, a heat in the 16-ton furnace will be described. The furnace was charged with 7·5 tons of Swedish pig iron and 9 tons of puddled ball from Bilbao hæmatite. These materials are charged straight into the furnace, the first charged being the pig iron. At 9-2 a.m. the charge was commenced, and melted at 2-40 p.m. The first iron ore addition of 60 kg. weight was made at 2-50 p.m., and another of the same weight at 3-15 p.m., followed by another of 50 kg. at 3-35 p.m. During the melting period and the following 45 minutes nearly all the silicon was oxidised. Some minutes after the third iron-ore addition, the ebullition of the bath commenced, which evidently proved that the oxidation of the carbon was energetically proceeding. The iron ore additions followed from time to time as the state of the bath indicated the necessity. The operation is conducted with the air valve closed as much as possible, so that the metal should not become cold, nor become oxidised. The total additions of iron ore amounted to 350 kg. At 6-25 p.m. the calorimetric analysis of the small sample taken from the bath and very slowly cooled gave a percentage of carbon of 0·52 per cent., and as the quantity required in the steel must be between 0·45 and 0·55 it was decided to tap the

furnace, making previously the suitable additions of alloys. These were ferro-manganese and ferro-silicon, putting 124 kg. of the first and 99 kg. of the second; the percentages required in the metal were 0·55 to 0·65 per cent. of manganese and 0·15 per cent. of silicon. This percentage is quite sufficient for obtaining a metal totally free from side and central cavities, except those at the top of the ingot and the pipe. The metal is poured into a Wellman ladle, previously well heated by producer gas. The ladle is then transported by the 50-ton electric crane to the casting pit, where the metal is poured into the mould.

Ingot Mould.—This is of cast iron, with a wash of refractory material, intended to retard the cooling of the metal at the top, keeping it fluid as long as possible, so that it may fill the space left vacant by the contraction of the metal in the rest of the mould. The mould both outside and inside has the form of a truncated pyramid (see Fig. 1). The sides of the inside pyramid, instead of being plane are curved surfaces joined to one another by rounding the edges. It seems natural that, since the elements of guns are cylindrical, the ingot moulds should also be of cylindrical form inside, and since also the steel, as it solidifies, crystallises in crystals whose axes are normal to the surface of the mould, the cylindrical form should be the best for obtaining good sound ingots without cracks. The reverse is what happens. The ingots cast in circular metal moulds have always a deep longitudinal crack, and thus are incapable of subsequent forging. In order to avoid the occurrence of cracks during solidification and subsequent cooling on the outside surface of the ingots, they are sometimes cast in refractory moulds. But though no cracks occur in ingots cast in such moulds, the long time spent in the cooling of a large ingot, cast in such manner, produces a very coarse crystalline texture, almost impossible of being changed to the proper texture during the forging. The experience at Trubia with 40-ton ingots cast in refractory moulds has been totally adverse to their use as substitutes for metal moulds for the part of the ingot really utilised. When this is completely solidified and almost cold on its outside, it is taken out of the mould and is covered with ashes until it is completely cool. After this it is carefully examined for cracks, which are dealt with by the pneumatic hammer. As it is not an easy matter to get rid of them entirely by these means, the ingot is sent to the forging shop, where it is subjected to a slight preliminary forging, just sufficient to give it a cylindrical form. Any cracks which were not visible in the preliminary examination then appear, and are taken out in the lathe. Some very good metal is thereby lost, but in the finishing up of the forging no cracks appear, and it is possible to finish the pieces with the least possible excess in the dimensions required for the hardening.

Before describing the forging, it may be mentioned that, about half-way through casting, operations are suspended for an instant, while a very small ingot is cast from the ladle. This is intended for the full analysis of the metal, and for forging a test-piece for a preliminary tensile test.

In order to study the segregation phenomena in the unfinished steel, the head from a 16-ton ingot was divided through its vertical axis. One of the halves of this head is represented in Fig. 2. From it were taken the samples for analysing the carbon, manganese, phosphorus, and silicon. The samples were taken only in one-half of the head, because it was presumed that the symmetrical parts of the other half must have the same composition, as the conditions of cooling were equal for both halves. The small ingot taken during the casting operation, which, owing to its very small dimensions, is free from the phenomena of segregation, and fairly represents the composition of the steel in the ladle (where it is supposed to be completely homogeneous), gave an analysis 0·56 per cent. of carbon and 0·57 per cent. of manganese. On comparing these percentages with those of the samples it is observed at once that there is not a very great difference between the samples taken at the circumference of the head and those of the small ingot. But the difference is very great in the samples taken in the centre of the head. Here, segregation phenomena are in evidence, especially with regard to carbon. It is observed that sample No. 1, from the bottom of the head, has the same quantitative composition as the metal of the small ingot, but in samples Nos. 2, 3, 4, and 5 the percentage of carbon increases gradually, being in sample No. 5 four times greater than in sample No. 1. The manganese increases also, but less so; the silicon more than the manganese, while the phosphorus in sample No. 5 is double that of No. 1. The layer of steel, in contact with the ingot mould, represents very nearly the composition of the metal, in fact the percentage of the metalloids is less. The layer successively cooling from the outside yields to the inside layers a certain part of its metalloids, until the central part of the ingot is reached, which, being the last to solidify and cool, is therefore richer in foreign elements. As the ingot mould is not closed, and is not in the form of a symmetrical cube, the segregation phenomena do not occur in the ordinary ingot mould in the manner described by Howe in his classical book, "Iron, Steel, and Other Alloys," as the "Onion type" of freezing. If the mould is a perfect cube, and the action of gravity be assumed to be counterbalanced, the segregation phenomena should occur in a completely regular manner, in layers parallel to the sides, and the metal richer in foreign elements will be exactly in the centre of the figure. In the casting of large ingots the segregation phenomena must occur as described, because the top of the ingot is the last to cool, especially if, as is the case at Trubia and elsewhere, the head of the mould is of refractory material, which contributes, to a great extent, in keeping the metal fluid longer than if this part of the mould were of metal.

FIG. 2.— ANALYSES OF THE SAMPLES TAKEN FROM HEAD OF INGOT. HEAT No. 1523.

Centre.

No.	Carbon.	Manganese.	Silicon.	Phosphorus.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1	0·565	0·525	0·187	0·024
2	0·672	0·610	0·210	0·029
3	1·176	0·620	0·230	0·029
4	1·607	0·620	0·261	0·036
5	2·484	0·610	0·284	0·049

Outside Surface.

No.	Carbon.	Manganese.	Silicon.	Phosphorus.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1	0·564	0·595	0·187	0·021
2	0·463	0·580	0·187	0·018
3	0·565	0·570	0·187	0·017
4	0·427	0·575	0·187	0·017
5	0·443	0·565	0·187	0·018
6	0·497	0·585	0·163	0·019

Analyses of Small Ingot taken during Pouring.

	Per Cent.
Carbon	0·562
Manganese	0·766

About 20 years ago Brustlein explained, in a report to the "Commission des Methodes d'Essai des Materiaux" in 1892, the lack of homogeneity of steel ingots and segregation phenomena in a manner very similar to that already explained in this paper, but without the aid of chemical analysis. His views as to segregation phenomena are in perfect accord with the manner of solidifying the iron-carbon solutions, as Roozeboom has explained in his diagram.

Applying their theories to the solidifying of steel ingots for gun tubes, it is easy to explain why the percentage of carbon increases from the outside layer in contact with the walls of the mould to the centre of the ingot, culminating in the greater amount of carbon and of the other foreign elements in the upper and central part of the ingot which is the last to set.

Fluid Compression.—Fluid compression consists, as everyone knows, in applying pressure to the steel while still fluid or semi-fluid. The process has acquired considerable development, and is extended to ingots of common steels, whereas it was at first only applied to ingots intended for the manufacture of guns or for the large shafts of ships. The older fluid compression method is that of Whitworth, whose patent was taken in 1866, the chief object of which was to obtain cast-steel ingots free from cavities.

The Whitworth process is undoubtedly a very good one, and, considered economically, it offers great advantages, but in practice not all the advantages of fluid compression are obtained. In one of the most important French steel works, where this process is applied to the ingots intended for the construction of guns, the author has had occasion to examine some of them, and has found that the pipe at the top does not entirely disappear.

In order to demonstrate that the Whitworth fluid compression process gives homogeneous ingots, that is, ingots free from segregation, it would be necessary to demonstrate it practically by dividing a large ingot longitudinally, and taking many samples for analysis, from all parts, or at least in the upper third. It is certain that in present-day practice, with the judicious use of deoxidising alloys in the furnace such as ferro-manganese and ferro-silicon, and perhaps with a very slight addition of aluminium during the casting operation, it is possible to obtain ingots free from cavities, except at the very top, in the central part, as is seen in the head of a 16-ton ingot, represented in Fig. 2. In this, as in all similar ingots, a very sound and homogeneous (78 per cent.) total mass was obtained. In favour of fluid compression it may be said that it causes the disappearance of the deep cracks, especially in the bottom of the ingot. Perhaps this is to be attributed rather to the lining of the inside of the ingot mould with refractory material. The cracks are always a serious defect, and sometimes, if ingot moulds of polygonal section without rounded corners are employed, and the block, after forging, is put on the lathe, they appear as dark lines along the total length of the piece, which correspond to the angles of the ingot. Certainly, in many cases the turnings do not break off when the tool cuts across the dark lines, but all the same the appearance of such lines does not suggest a very good quality of metal.

With regard to the improvement of the mechanical properties by fluid compression, the author must say that it is not very evident to him. Perhaps it is assumed that fluid compression during the last period of the process, when the metal is in a semi-fluid state and almost set, confers an effect similar to forging. In Whitworth fluid compression, after the expulsion of the gases, the press does not cause any deformation in the ingot, and there cannot be forging without deformation. Some years ago a new fluid compression process was patented by Messrs. Robinson & Rodgers, of Sheffield, in conjunction with Mr. Illingworth, of New York. This process has been described by Mr. A. J. Capron.* The advantages derived are that absolutely sound ingots are obtained free from cavities and pipe, so that the whole of the ingot can be utilised, without any waste. As it is possible to watch, during the compression, the top of the ingot and the setting of the liquated part of the steel, a great improvement in the quality of the metal can be obtained. The ingots are poured in the same place as they are compressed. The plant is very simple and economical, and can be operated by men without special training, and, the ingot moulds being in halves, the top and bottom sections are equal, which facilitates the rolling.

Another compression fluid process, which has become very well known and accepted during the last years, and is widely adopted in France, England, and Germany, is that patented by Mr. Harmet, of St. Etienne, which has also been fully described by him to the Iron and Steel Institute.†

In concluding this part of the paper, the author would repeat that in his opinion the principal advantage to be derived from fluid compression lies in its economical aspect. When casting under ordinary conditions, it is possible to utilise from 75 per cent. to 80 per cent. of the ingot, while with compression it is possible to reach 90 per cent.

(*To be continued.*)

* "Journal of the Iron and Steel Institute," 1906, No. 1, page 28.
† "Journal of the Iron and Steel Institute," 1902, No. 2, page 146.

AN ANALYSIS OF ACCIDENTS IN A MACHINE TOOL WORKS.*

BY L. D. BURLINGAME.

In making a study of safety methods and safety devices, an analysis of the accidents that have occurred in a large machine shop may be of service for still further protecting the workmen when engaged in their various lines of employment. A careful record of all accidents in the works of the Brown and Sharpe Manufacturing Company has been kept during the last seven years, and a study made of them for the purpose of ascertaining where danger is greatest, what accidents are preventable, and how best to avoid them. It may be said that in this factory extra care has been taken for many years to guard against accident, and the management has never hesitated to spend money for that purpose when convinced that it would bring about safer conditions. During the last year an additional effort has been made to profit by past experience both at our own works and by the experience of others, and still further to tune up the safety equipment and spirit of the organisation in order that accidents might be reduced to a minimum.

When this additional work was undertaken, about a year ago, an analysis of all accidents which occurred during the previous six years was made along three lines: (*a*) the percentage of accidents under each of 18 headings from different causes; (*b*) the percentage by departments of the shop, divided into more than 30 groups; (*c*) the seriousness of the injury and the resulting length of disability from work. Following this, a similar record is being kept each year showing (*d*) what kinds of accidents are increasing, and what kinds are being decreased by the further safety methods being adopted, also which departments are reducing their accidents and which are growing worse. The different kinds of accidents were classified as follows, and the percentages given are for the six years preceding the date of the investigation, *i.e.*, 1905 to 1910 inclusive:—

	Total Accidents.	Percentage.
Caught in machinery	78	7
Caught or struck by belt	23	2
Set screw or other projection	29	2·6
Falling on or striking workman	226	20·1
Workman falling or strain lifting	75	6·7
Machinery starting unexpectedly	8	0·7
Chain or rope slipping or breaking	10	1·0
Punch press, rolls, or shears	20	2
Cutters and metal saws	94	8·5
Handling work or chips—eyes	126	11·2
Woodworking machinery	47	4·2
Burns, including electricity	79	7·0
Cuts with sharp instruments	20	2
Jams and hammer blows	71	6·3
Caught in tool and work (not cutters)	176	15·7
Elevator	4	0·5
Fooling	13	1·2
Litter or dark places	15	1·3

These accidents naturally divide into two groups: (1) those caused by machinery, either (*a*) by being caught in the gearing, belting, or other parts of the machinery, or (*b*) by being injured by the cutter or other tool or caught between the tool and the work; (2) those caused by falling, jams, burns, cuts, &c. The first group includes 42·7 per cent. of the accidents occurring during the six years, divided as follows: group (*a*) 12·3 per cent.; group (*b*) 30·4 per cent. This leaves 57·3 per cent. as the proportion of accidents occurring under the second group.

From the above analysis it will be seen that if complete guards could be provided so that every accident due to being caught in gearing, on set screws, or anywhere in the mechanism of machinery would be avoided, it could at most only reduce the accidents 12·3 per cent. Several recent occurrences show the unexpected accidents which result from this cause. A workman, hearing a rattling in the knee of a milling machine he was running, reached his hand underneath to see

* Paper presented before the April, 1912, meeting of the Providence Association of Mechanical Engineers (affiliated with the American Society of Mechanical Engineers).

if the cause were due to a collar which he thought might have become loose, and stuck his finger into the running gearing.

Another case was that of a workman who reached for a can of oil which he had left on a ledge of the machine. In lifting it up he caught a finger in the pump gears back of the guard. Both of these accidents occurred on machines considered sufficiently guarded, and to experienced workmen, indicate that to have complete safety it may be necessary to enclose all gearing entirely, whether or not it is exposed.

A way of preventing accidents by being caught by set screws or other projections, also coming under this division, is to insist on the wearing of short-sleeved jumpers, to avoid loose clothing, hanging neckties, &c. One of the apprentices at the Brown and Sharpe Manufacturing Company's works was injured recently by having the pocket of his jumper catch on the set screw of the revolving dog while he was filing. All of the boys running machines at this plant are obliged to wear short-sleeved jumpers, and the men are advised to. Seventeen of the accidents reported were due to being caught by the sleeves of the jumpers.

The company is now experimenting with various forms of safety dogs, none with the projecting set screws having been added to the equipment during the last year. The plan of changing the regular dogs for headless screws adjusted with a socket wrench is also being tried experimentally.

The accidents in group (*b*) are more frequent and more difficult to guard against. It is practically impossible in many cases to do guarding at the point of cutting, and if guarding is attempted it may introduce dangers greater than those sought to be avoided. It is, however, possible to insist that the fingers shall never be used to wipe off chips, &c., from a running cutter. Out of the 94 accidents from cutters reported, 30 were caused by being caught when wiping off chips with the fingers.

In the use of punch presses 20 accidents had occurred in the period investigated, so this was one of the first matters to be considered. The means adopted for guarding against these accidents were novel, as far as the author is aware, and have proved fully successful both in avoiding accidents and in preventing an appreciable increase in cost of doing the work. A rule was made that the fingers and hands must never be put between the punch and die. Tweezers and pliers were furnished for handling the work, the points being shaped in some cases to suit particular jobs. The only accidents since have been to the points of the tweezers and pliers. Chutes have also been used to slide the work into position, a stick being used to remove it after the operation. For some work which it was thought could not be handled by the above means, a swinging fixture was designed, so that the work can be put in place away from under the punch and then swung into position for the operation.

The 47 accidents from woodworking machinery were largely cuts from circular saws, but included eight where the block of wood was thrown back when slitting, two of the cases being fatal, the only fatal accidents in the works during this period. The men are now required to wear a heavily padded apron when using a slitting saw, and this has, it is believed, saved the lives of several workmen. The use of a "spreader" when properly installed helps to prevent such accidents by keeping the cut from closing in back of the saw.

Another prolific source of accidents which, while not serious perhaps, are painful, is in being cut by revolving grinding wheels, especially when doing internal grinding and trying the plug in the hole without running the wheel back a sufficient distance. Twenty-eight of the accidents were from this cause. A shield has been designed which automatically swings up in front of the wheel so as to protect the hand if the plug should slip.

Under the second group, falling, jams, burns, cuts, &c., a large proportion of the accidents are entirely within the control of the workman, either the one hurt or a fellow workman, and the remedy is largely to be found by employing careful methods. In this, however, the foreman can exercise a large influence for safety. Some specific remedies can also be applied. It was found that 37 cases of burned feet in the foundry had resulted from wearing laced or low shoes. A rule was made that high shoes without lacing should be worn, and a supply of such shoes is kept and sold to the foundrymen at about cost. This has nearly remedied the trouble. There remains, however, the liability of the iron spattering into the tops of the shoes and burning the legs when the pants are ragged. A study is being made of the possibility of using pants made of non-burnable material.

About one-fourth of all the accidents are caused by weights falling on the workman and jamming or cutting either the hands or the feet, and from the workman himself slipping and falling. The remedy here is to use care that safe methods are employed, and that men do not take chances. Classified with these are 13 accidents traceable to "fooling," some occurring outside of working hours.

In considering the classification by departments and kinds of work, it was found that, for the period of six years, the average number of accidents was greatest in the following departments, the percentage of employés injured each year being as follows: (*a*) *Grinding department*, 13·8 per cent., being caused largely by cuts from grinding wheels. This has been much reduced during the past year, so that this department now ranks eighth instead of first in order of accidents. (*b*) *Labourers*, 10·6 per cent., largely from injury by falling objects, jams, strains in lifting, and the workman falling. (*c*) *Carpenters*, 10 per cent., a large proportion of the injuries being due to woodworking machinery. (*d*) *Foundry*, 9·5 per cent., due mainly to burns, also to falls and falling objects.

Then follow the various machine departments from 7·6 per cent. down to 2·2 per cent., and ending with the inspection department, the offices, and the draughting department, with the percentage coming down to 0. Only four elevator accidents, and these slight, occurred during the six years, a very good showing with more than a dozen elevators in constant operation.

In the classification by seriousness of injury and length of disability of 1,124 accidents occurring during the period of six years covered, 382 resulted in no disability, that is, no absence from work. In 457 cases there was less than one week's absence from work. Of the remaining 285 cases, 132 resulted in between one and two weeks' absence; 74 in two to four weeks' absence; 51 in one to three months' absence; 5 in three to six months' absence; and 5 in over six months' absence; in addition, eight were hurt so as to cause the loss of an eye, a foot, or permanent injury, two dying from the effects of their injuries. Ten men left, and no record was kept of the duration of their disability. These statistics form a good basis for future investigations looking towards a still further accident reduction.

In 1911, with an average of 4,050 employés, there were 243 accidents, or about 6 per cent. of the workmen were hurt sufficiently to report; this on a basis of reporting slight accidents as well as those of a more serious character. Some of the added measures for safety had been in operation during part of the year, so that the gain from 6½ per cent., the record of the previous year, to 6 per cent. for 1911, indicated a gain due to such further safeguarding. This gain was also shown in the reduced number of serious accidents included in last year's list. There were no fatal accidents; no loss of eye or limb, and more than 70 per cent. of the reported accidents resulted either in no disability or in less than one week's loss of time.

In some few departments, where accidents increased during the past year, special steps are being taken to ascertain the cause and to avoid a repetition. Each accident is studied to learn the lesson it teaches as to further methods of safety. It is hoped by such means to reduce the accident list to a minimum for the benefit of both workmen and employers.

The "Titanic" Judgment.—Lord Mersey's judgment respecting the loss of the White Star liner "Titanic" will, it is reported, be read at an adjourned meeting of the Commission of Enquiry to be held next week. Some days ago Lord Mersey, it will be remembered, addressed significant questions to the Board of Trade during the enquiry, and when the report is issued it will probably be found that the answers have had an important influence on both text and recommendations. The Advisory Committee on Merchant Shipping is also expected to publish the result of its investigation in the next few days, but the Bulkheads Committee is reported to be still a long way from the end of its labours.

HIGHLY-SUPERHEATED STEAM IN LOCOMOTIVE SERVICE.*

BY G. E. RYDER.

AMONG all recent improvements in the design and construction of the locomotives, the use of highly superheated steam is attracting the most attention among motive power and transportation department officers. The interest displayed by railroad men in the use of superheated steam is not, as it was a few years ago, interest in a new device accompanied with the wonder whether or not it would be successful, but rather an interest of wonder at the success of the device shown by the results that have been obtained in the saving of fuel, decrease in water consumption, and the increased hauling capacity of the locomotives.

From the results that have been obtained with superheaters in service it is conservative to say that the saving which has been effected in the fuel consumption under average working conditions is 25 per cent. This saving is so large that we are liable to overlook the significance of the fact that this really means an increased hauling capacity of 33⅓ per cent. Assume that there are being burned in a saturated locomotive 6,000lbs. of coal per hour, and that this is the limit of the fireman's capacity. Assume also that the efficiency of the locomotive is such as to produce one horse-power for each four pounds of coal. Under these conditions there are being developed 1,500 horse-power hours per hour. Now suppose that this same locomotive be equipped with a superheater, by the use of which it is possible to save 25 per cent. in fuel, that is, the consumption is now 3lbs. of coal per horse-power hour, or 1,500 horse-power hours on 4,500lbs. of coal. But since the capacity of the fireman, as was assumed, is 6,000lbs. of coal per hour, it is possible with the superheater locomotive to develop 2,000 horse-power hours per hour, an increase of 500 horse-power hours, or 33⅓ per cent. This increase of 33⅓ per cent. in horse-power hour means an equivalent increase in hauling capacity, which is the real item of importance to the mechanical and operating departments, inasmuch as it means a decrease in the investment in power and a corresponding decrease in the operating costs to handle a given amount of traffic.

Dry or moderately superheated steam has been frequently tried, but with little economy compared with the remarkable results obtained with a high degree of superheat. Many forms of superheaters designed to be located in the smoke box of an intermediate combustion chamber have been tried, but with unsatisfactory results. The smoke box type is open to serious objection in that it obstructs the front end. Furthermore, in some designs there is a high cost of maintenance due to the corrosion of the pipes and their deterioration occasioned by the abrasive effect of the cinders. These mechanical defects have not been as instrumental in the abandonment of this type of superheater, however, as has the fact that but little economy is obtainable through the low degree of superheat which they produce. On the other hand, the fire tube superheater, by the use of which a temperature of the steam entering the cylinders of from 600° to 650° or a superheat of from 200° to 250° may be obtained, has been almost universally adopted by railroads using superheated steam, because of the largely increased efficiency of the locomotive using such degree of superheat. At present there are something over 12,000 locomotives in all countries equipped with fire tube superheaters, over 2,000 of this number being in service in the United States.

The principal advantages secured through the use of highly superheated steam are due to the increased volume of steam delivered per pound of water evaporated, and the prevention of cylinder condensation. The economy which results from the use of the superheater is occasioned by the reduction of what is known as the "missing quantity," or the difference between the actual steam passing through the engine and that which is shown by the indicator card. This quantity is largely due to the loss by condensation in the passages to the cylinder and in the cylinder walls themselves.

In considering the qualities of saturated steam we find that it has the same temperature and pressure as the water from which it is evaporated, and with which it is in contact, and that for each pressure the steam has a certain constant temperature. At 170lbs. boiler pressure, for example, the steam will always have a temperature of 375° Fah., and a volume of 2·47 cub. ft. per pound. If more heat be added to the boiler it is transmitted to the water and used in evaporating more water, but it does not increase the steam temperature as long as the pressure remains the same. If heat be taken away from the saturated steam in doing work or by cooling, as in the steam passages of the cylinders, part of the steam condenses. The amount of the steam condensed is almost proportional to the heat abstracted and this condensation is inert so far as the capacity for further work is concerned.

Condensation takes place in the steam chests, in the cylinders, and in the passages from the boiler to the steam chest. The greatest loss from condensation occurs in the cylinders, for here the variation in temperature is widest, and the large areas offer a favourable condition for the loss of heat or for condensation to take place. The steam enters the cylinders practically at boiler pressure (disregarding the loss of condensation in the passages and the steam chest and other conditions which influence the pressure). Assume, for example, that the boiler pressure is 200lbs. per square inch, then the steam enters the cylinders at a temperature of practically 387° Fah. It finds the cylinder walls in a comparatively cool condition. Immediately these cool walls begin to rob the steam of its heat, and this they continue to do throughout the stroke. The steam leaves the cylinder at a temperature corresponding to the pressure of exhaust, or

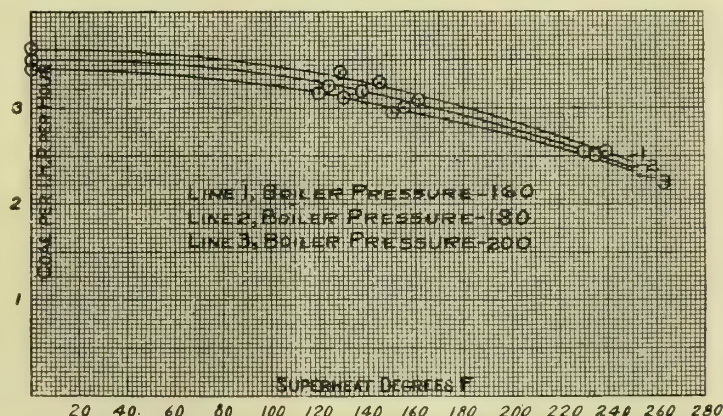


FIG. 1.—CHART INDICATING SAVINGS RESULTING FROM THE USE OF SUPERHEATED STEAM.

about 230° to 240° Fah. It also leaves the temperature of the cylinder walls about the same as the temperature of the exhaust, and the next admission of steam, which, by-the-way, enters the coolest end of the cylinder, finds the cylinder walls in this cool condition, and must go through the same process as the preceding admission. Thus all the steam which enters the cylinders must go on giving up heat to the cylinder walls and thence to the atmosphere. This drop in temperature, and the corresponding loss of heat of saturated steam means a corresponding amount of condensation and a proportional drop in pressure. Tests show that, in Mallet compound engines without superheaters, the condensation in the receiver pipe amounts to as much as 20 per cent., while in simple saturated engines using short cut-off, cylinder condensation runs up to over 35 per cent. of the weight of steam admitted to the cylinders; that is, for every 100lbs. of steam delivered to the cylinder only 65lbs. are available for doing work. This loss is overcome by the use of highly superheated steam.

As for the qualities of superheated steam, when steam has left the boiler and has passed into the superheater it is no longer in immediate contact with the water from which it was generated. If heat be now added to the steam in its passage through the superheater tubes, the moisture is evaporated and additional heat is absorbed by the steam, so that on reaching the high-pressure steam chest it has a temperature of about 200° Fah. above that which it had when leaving the dry pipe; meaning that it reaches the high-pressure steam chest at an actual temperature of about 600° instead of 390° or 400°, as

* Abstract of paper read before the Southern and South-western Railway Club, Atlanta.

is the case in a saturated steam engine. The pressure of the superheated steam, however, is practically the same as in the boiler. Superheated steam partakes of the nature of a perfect gas. It has a larger volume per unit of weight than saturated steam, and, like a gas, is a poor conductor of heat, giving up its heat to the cylinder walls and steam pipes less rapidly. Taking superheated steam in the same proportions that were used in the case of saturated steam at 170lbs. pressure with 200° degrees superheat, it is found to have a volume of 3·27 cub. ft. per pound as against 2·47 cub. ft. per pound for saturated steam. Of course, when superheated steam passes from the superheater to the comparatively cold cylinder walls, some of its heat is given up to these walls and the passages traversed in reaching the cylinders, but the condition differs from that of saturated steam in that it does not condense until it has lost all of its superheat, and therefore the superheater must be so designed that under all working conditions it furnishes more superheat than the steam can lose by condensation in the cylinders.

The curve shown in Fig. 1 shows the saving which is effected in the pounds of coal per indicated horse-power hour for various degrees of superheat. It also shows that the saving is very small for low degrees of superheat and increases more rapidly for higher degrees of superheat. Referring to the curve, it will be noted that with a steam pressure of 180lbs. from 0° to 160° of superheat, a saving of $\frac{1}{2}$lb. of coal per indicated horse-power hour was effected, while an equivalent saving is again effected in the next 60° of superheat. Reference is made to this subject in a report to the Railway Master Mechanics' Association in 1910 as follows: "The coal

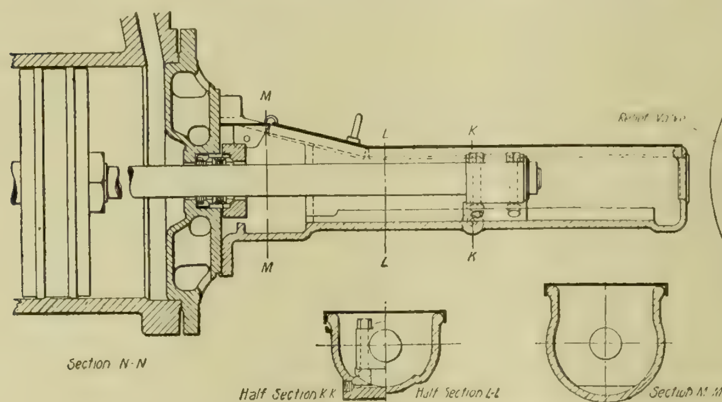


FIG. 2.—PISTON ROD EXTENSION GUIDE.

consumption per indicated horse-power hour at 180lbs. steam pressure for the locomotive using saturated steam was 3·50lbs., and for 80° of superheat was 3·40, a gain in efficiency of 2·8 per cent., while the consumption at 160° superheat is 3lbs., a gain of 14·8 per cent., which is five times the saving of the first 80°. Now if this line indicating a steam pressure of 180lbs. is carried as a smooth curve to 240° superheat, as shown, it would indicate a coal consumption of 2·35lbs. or a saving over the saturated engine of 32·8 per cent."

The effect of the superheater on the boiler is to increase the boiler capacity in proportion to the decrease in the demands that are made on it from 25 to 35 per cent. It has been shown that as the demand for power is increased the degree of superheat increases, so that the demand on the boiler does not increase in proportion. It is therefore economical to force a superheater engine, while it is not economical to force a saturated boiler in the same way, and it is many times impossible to do so for any length of time. The fact has been proven that locomotives equipped with superheaters developing high degrees of superheat have at least 25 per cent. greater boiler capacity than the same size of engine without a superheater. As the engine is worked harder, the fire is forced, which means a higher fire-box temperature and hotter gases in the superheater. This results in a higher temperature of the steam, and with this higher superheat there results the greater efficiencies which are characteristic of the superheated steam locomotive when being worked hard. This fact explains the variation in fuel saving obtained by different superheater locomotives, and emphasizes the fact that the greater economies are obtained when the engine is being worked the hardest.

In engines operating in poor water districts, where foamy water and fluctuations in water level would tend to increase the amount of water carried over from the boiler, it can readily be seen that a device which reduces the demand on the boiler, and which will in addition prevent the water from reaching the steam chest and cylinders, will greatly lengthen the life of the valves and pistons, prevent breakage of the cylinder heads from water pressure, and also lengthen the life of the boiler. Another feature which favours the boiler in the use of superheated steam is the comparatively low boiler pressure which may be carried, since the size of the cylinders is not limited, as in the saturated steam engines, where the diameter of cylinder must be limited in order to reduce condensation. Standard recommendations for boiler pressures to be used in connection with superheaters are 180lbs. for freight engines and 200lbs. for passenger engines. In bad water districts even lower boiler pressures may be used with correspondingly enlarged cylinders. The use of the brick arch in connection with the superheater favours higher degrees of superheat. The arch acting as a baffle wall produces a longer flame-way, giving the gases a greater time to mix with the oxygen, and thereby produce more complete combustion, resulting higher temperature in the fire box and the flues. It also has a tendency to direct the hotter gases through the large flues which are located in the top part of the boiler.

From the foregoing the requirements for an efficient and practicable fire tube superheater may be summed up as follows: An integral header which in no way obstructs the front end or interferes with the maintenance of the boiler tubes, so designed as to cause the least tendency toward wire drawing of the steam; an arrangement of superheater pipes which makes them easily accessible and removable, and so constructed that the unequal expansion caused by the difference in temperature as the steam passes through the tubes will be taken care of; and a set of superheater flues located in the upper part of the boiler, where the tendency toward clogging is least and the temperature is highest.

Referring now to the requirements regarding the engine details coming in contact with superheated steam, the joint rings between steam pipes and header and steam pipes and cylinders should be made of cast iron, as brass rings, on account of disintegration, do not so successfully withstand the high temperature. Piston valve rings and piston rings and bushing should be of close-grained cast iron. Too much attention cannot be given to the quality of the material in these parts. The ordinary designs of piston rod packing have given satisfactory service, but the alloy used for the packing rings should have a higher melting point than is usual in these parts where saturated steam is used. An alloy of 80 per cent. lead and 20 per cent. antimony has proven satisfactory. Another very essential requirement in connection with the superheater locomotive is the use of good oil and continuous lubrication. The system found to be best adaptable for a simple 2-cylinder engine is a 5-feed lubricator, the leads to be into the steam pipes or the centres of the steam chests and into the centres of the cylinders, the fifth feed to lead into the air pump steam pipe in the ordinary manner. The feeds to the steam chest should enter the centre of the steam chest and should not be branched off. The steam chest should get three or four drops of oil for each drop fed to the cylinder. Vacuum valves of ample size on each steam chest are more essential in a superheater engine than in ordinary engines on account of the higher temperature of the steam chest cylinders. While the engine is working, the oil is sufficiently protected by the steam against carbonising; while drifting, however, the oil has no such protection, and on account of the high temperature of the steam chest walls would have a tendency to carbonise, which can be overcome by the use of vacuum valves to let in cold air. For similar reasons the use of drifting valves is recommended, or at least that the throttle be cracked at the beginning of a long stretch of drifting.

The piston rod extension guide has also been found to be of considerable value in reducing the wear of cylinder bushings and cylinder packing rings. The extended rod riding on guides relieves the cylinder bushings and rings from the weight of the piston, and thereby reduces the friction and the wear upon them. The design of the extended piston rod which is illustrated in Fig. 2 has been applied to a large number of superheater engines during the last 12 months with satisfactory results. This design was brought forth by Mr. F. J. Cole, chief consulting engineer of the American Locomotive Company. The history of the extended piston rods is marked by a large number of designs which have not been successful. A piston rod extension guide to be satisfactory must be of simple yet rigid construction, easy to lubricate, and easily removed without interfering with other parts of the locomotive, and, above all, it must have an ample bearing surface, a feature which was lacking in all of the earlier designs of guides for this purpose. It will be seen from the illustration that the principle of the present style of extended rod guide is that of a miniature crosshead sliding on a cylindrical surface, which is rigidly supported on and is easily attached to the cylinder head. The design permits of adjustment being easily and quickly made by lining up between the small crosshead shoe and the body. The packing on the extended rod is easy of access and can be attended to without difficulty. The guide for this crosshead is self-centred on the circular flange of the cylinder head and thereby requires no adjustment in sefvice, as it cannot get out of position. Another feature of this design is that the guide is made with an open top so that when it is necessary to remove same it can be dropped from the rod and does not require a large amount of space ahead of the cylinder.

The superheater can be successfully applied to any of the existing types of locomotives, provided these locomotives are equipped with piston valves. By this application the boiler capacity can easily be increased 25 per cent., and it will be possible to haul correspondingly heavier trains on the same schedule or the same trains on a proportionally faster schedule. It has been found in many cases that trains double-headed with saturated steam engines can be handled with one superheater engine. It has also been demonstrated that a saturated passenger engine capable of hauling seven cars, after being equipped with a superheater, can handle eight or nine cars on the same schedule; providing, of course, that the cylinders are of such size and the adhesive weight is sufficiently great to enable the engine to start the additional load. Boiler maintenance is also reduced in that it is possible to reduce the boiler pressure, if the construction of the cylinders be such that their diameters may be increased. By increasing the size of the cylinders without decreasing the boiler pressure the engine is given a greater starting power and the increased boiler capacity will more than take care of the demands of the larger cylinders for steam.

In summing up briefly the advantages of highly-superheated steam in locomotive operation, we have directly a saving in fuel of about 25 per cent., a saving in water consumption of 35 per cent., and by the utilisation of this economy, an increased hauling capacity of 33⅓ per cent. is made possible. Further, locomotive construction for the use of saturated steam had about reached the limit on account of the inability of the fireman to supply the boilers with the greater amount of fuel demanded. This limit has now been extended to the amount of the fuel saving or about 25 per cent., and makes possible a more powerful engine per unit of weight than has hitherto been available.

THE INEFFICIENCY OF OUR PRESENT LIGHT SOURCES.

In the course of a paper on "Illumination: Production, Calculation, Measurement," read before the Glasgow section of the Institution of Electrical Engineers, Mr. J. D. Mackenzie referred to the inefficiency of our present light sources, and the direction in which advances are to be made.

To produce light, he observes, requires energy, just as it does to produce heat, but while we can obtain an efficiency approaching unity for the conversion of electrical energy into heat we fall lamentably short in converting that same energy into light. The mechanical equivalent of heat is well known, and has been determined by numberless experiments carried out by many experimenters and by various methods. The mechanical equivalent of light is not so well known or so generally understood, and yet it has been the subject of careful investigation by many prominent workers in the domain of pure and applied science. Dr. C. V. Drysdale some three years ago ("Illuminating Engineer," London, August, 1908) collected and tabulated the results of most of these investigations, to which were added the results obtained by himself and Mr. Jolley. From the table (Table I.) it will be seen how far short we come of the possible efficiency in this matter of light production. When it only requires 0·05 to 0·1 watt per candle-power to produce light, the tungsten lamp giving 1 c.p. per 1·25 watts, has only a possible efficiency of 4 to 8 per cent.

TABLE I.—*Mechanical Equivalent of Light.*

"Illuminating Engineer" (London), 1908.

Observer.	Date.	Method.	Source.	Unit.	Mechanical Equivalent.			
					Calories per Second.		Watts.	
					Per Hefner.	Per Candle-power	Per Hefner.	Per Candle-power.
J. Thomsen	1863	A	Sperm candle	Sperm candle 8·2 grammes per hour	0·06500	0·0733	0·2760	0·3075
	1863	A	Moderator lamp		0·05850	0·0650	0·2450	0·2720
	1863	A			0·06150	0·0683	0·2570	0·2860
	1863	A	Gas flame		0·06300	0·0700	0·2640	0·2939
	1863	A			0·05530	0·0615	0·2320	0·2580
O. Tumlirz and Krug	1888	A	Incandescent platinum wire	Hefner	0·04100	0·0455	0·1715	0·1900
O. Tumlirz	1889	A	Hefner lamp	Hefner	0·04550	0·0505	0·1910	0·2120
K. Angström	1903	C	Hefner lamp	Hefner	0·02590	0·0288	0·1085	0·1210
Author and A. C. Jolley	1907	C	Nernst filament	Candle	0·02560	0·0284	0·1070	0·1190
	1907	C	Arc	Candle	0·01730	0·0192	0·0725	0·0805
	1907	C	Monochromatic yellow green	Candle	0·01285	0·0143	0·0538	0·0598

Method A.—Thermopile and absorptive screens.
Method C.—Direct measurement of energy in spectrum.

The attainment of very much higher efficiencies from incandescent solids is scarcely to be expected owing to the long range of invisible heat vibrations at the one end and invisible ultraviolet vibrations at the other end of the spectrum. Of course, the light emitted by an incandescent solid increases very quickly with an increased temperature, owing to the fact that the luminous intensity varies as the fifth power of the absolute temperature of incandescence. The limit of the carbon filament was reached long ago in the high efficiency lamps, and was fixed not by the melting but by the vaporisation of the carbon. With the metallic filaments the temperature at which they can be worked commercially is fixed by the melting-point of the metal, and must be so placed as to permit of a reasonable margin to allow for increases in the current due to ordinary fluctuations of supply. This limit has practically been reached. Hence, unless some solid having a selective emissivity for light vibrations is discovered, we must look

for other means of obtaining high efficiencies. In the vapour lamp the efficiencies obtained are higher, but with the exception of the Moore vapour light, which has some constructional and installational defects, the colour of the light obtained from the commercial vapour lamp is objectionable for general purposes. Methods have been adopted for obviating this complaint, but, with the exception of fluorescent reflectors, all these methods result in a decreased efficiency. Tests of the light efficiencies for the mercury arc give values from 5·8 to 17·6 per cent.

There are two ways in which the efficiency from an incandescent solid might be increased. It is possible to transform some of the dark heat vibrations by means of calorescence into light, and on the other hand, by means of fluorescence to degrade the ultraviolet vibrations into the visible portion of the spectrum. This latter principle is being used in the construction of the so-called "white light" Cooper-Hewitt mercury vapour lamps. A reflector, coated with a prepared paper surface dyed with a solution of rhodamine, is fitted behind the luminous tube. The radiations from mercury vapour comprise principally a yellow ray of wave-length $\lambda=0{\cdot}578\ \mu$, a green ray of $\lambda=0{\cdot}546\ \mu$, a blue ray $\lambda=0{\cdot}436\ \mu$, a violet ray $\lambda=0{\cdot}303\ \mu$, and several ultraviolet rays, only one of which ($\lambda=0{\cdot}366\ \mu$) passes through the glass of which the Cooper-Hewitt tubes are formed. The effect of the rhodamine reflector on these rays is that the yellow and green are absorbed and transformed into red rays, the blue is unaffected, and the invisible ultraviolet is also absorbed and degraded into visible red rays.

What the effect of this absorption and transformation of light radiations has on the total efficiency of the lamp I am unable to state. I should imagine that a reflecting surface and substance which would not absorb the yellow rays while absorbing and converting the green rays would be more efficient as a light-producing arrangement. It is well-known that the maximum visual vacuity of the human eye is in the vicinity of these yellow rays (about $\lambda=0{\cdot}58\ \mu$). Whether such means as these can be commercially applied to increase the efficiency of our light sources is matter for experiment and investigation, but probably at best the increase would not be very great nor very lasting. The Cooper-Hewitt reflectors are only guaranteed for a life of about 1,000 hours, the effect of the rhodamine dye wearing off in about that time. The distance we have to travel towards increased efficiency is enormous. The fire-fly and glow-worm have a lighting efficiency of practically 100 per cent., and the production of light with an efficiency approaching this figure is the problem still waiting solution.

The increased efficiency of the flame arc lamp over the ordinary open type arc seems to be due in some measure to the fact that the incandescent vapours in the arc space emit a very large proportion of the total light. It is possible to show this experimentally by the spectroscope, the well-known band spectrum, due to incandescent vapour, being clearly shown.

REFRIGERATION PLANT FOR DRY AIR BLAST.

MR. JAMES GAYLEY in "The Iron Age" gives a description of later methods of applying the 2-stage system of refrigeration for dry air blast, which, he claims, are more economical in construction and operation than the earlier methods.

In the first method of installing dry air plants the moisture was extracted by passing the air over coils of pipe, which were cooled to a low temperature by the circulation of brine; and while this method has proved effective in practice, cheaper methods have since been worked out. On the principle that it is easier to go from one temperature to another by a succession of steps, rather than by a single step, several methods of applying the 2-stage system have been evolved, which, while producing the same results, are more economically operated and can be installed much more cheaply. The accompanying illustrations show various types of refrigerating chambers.

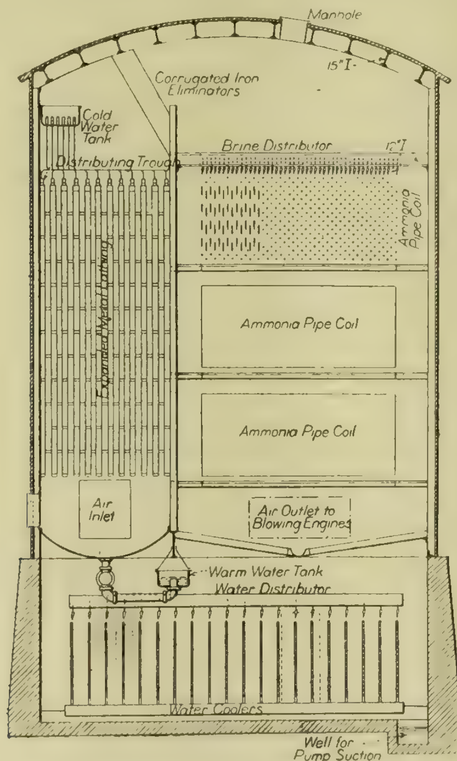


FIG. 1.—TWO-STAGE REFRIGERATING CHAMBER. COOLING BY DIRECT AND INDIRECT CONTACT.

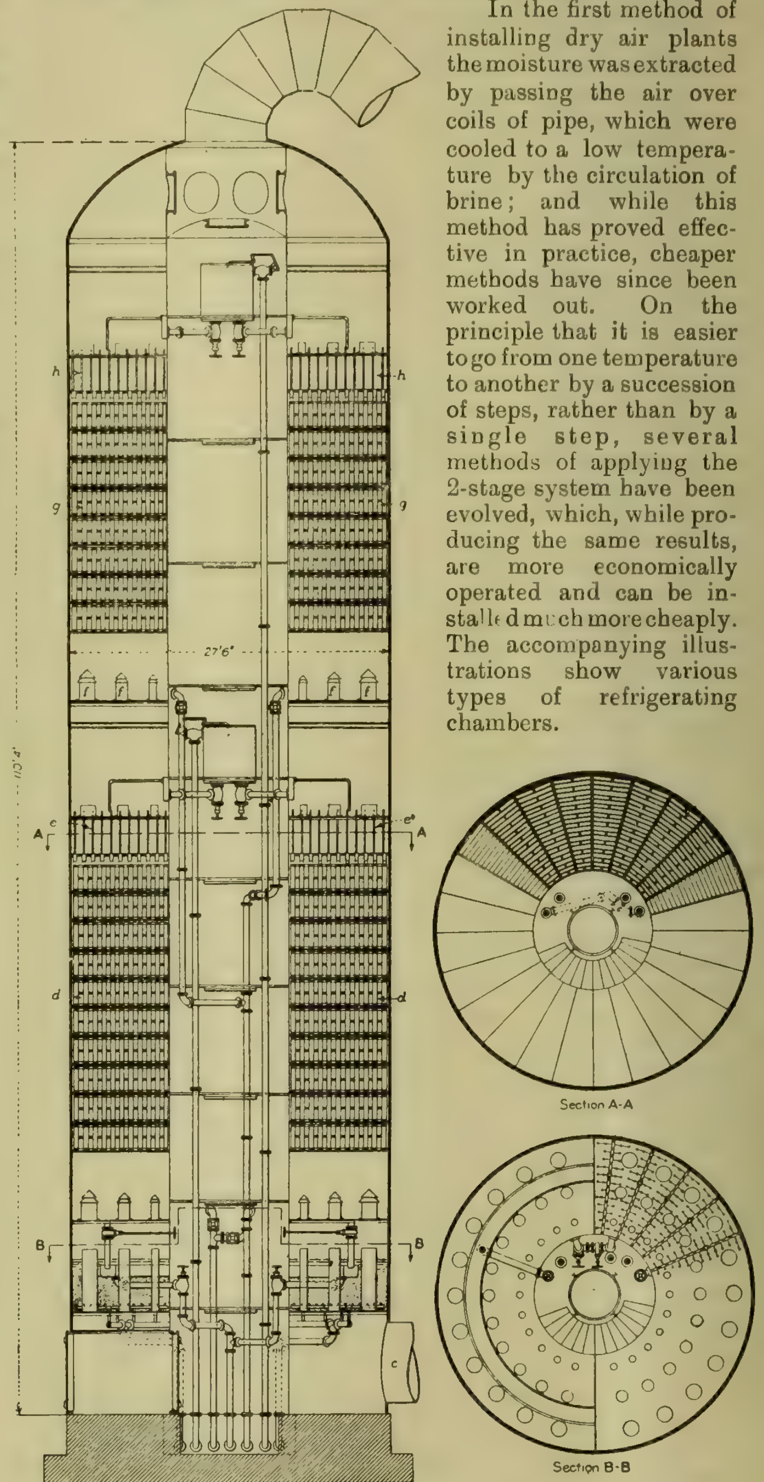


FIG. 2.—THE TALL TOWER TYPE. REFRIGERATION ENTIRELY BY DIRECT CONTACT.

Fig. 1 shows a 2-stage refrigerating chamber, which represents cooling by a combination of direct and indirect contact. One chamber is filled with screens and the other with coils of

pipe. These screens may be made of expanded metal lathing, separated by baffle strips, causing the air to pursue a tortuous course. The air passing up through the screens is met with a descending shower of water, which is cooled as closely as practicable to the freezing point. This removes about two-thirds of the moisture. The air then passes up through moisture eliminators, in which any entrained moisture is removed, and afterwards passes downwardly over the refrigerating coils. A small stream of brine is allowed to flow over the coils, and this film of brine prevents the formation of frost. Consequently the operation of the chamber becomes a continuous one, and the work done in the coil chamber is practically constant, as the air leaves the first chamber at the same temperature. The cooling water with that from condensation collects in the cooling chamber underneath, where it is kept at a practically constant temperature, and the surplus accumulated by the condensation of the atmospheric moisture can be used for other condensing purposes.

Fig. 2 represents the tall tower type, designed by Bruce Walter, of Pittsburg, to conduct the refrigeration by direct contact entirely. This has capacity for a furnace requiring 40,000 cub. ft. per minute, while Fig. 3 is for a furnace requiring 25,000 cub. ft. per minute. The variation in design is made to meet any limitation of ground space that would be likely to present itself at any furnace plant, and requiring no more than a hot blast stove.

In Fig. 2 the air enters at *c* and passes up through pipes to the chamber *d*, which is filled with screens or grids, over which flows a constant stream of cold water. The air is thus brought into intimate contact with the water and the greater part of its moisture is condensed and removed. Next the air passes through the moisture eliminators *e*, then through the outlet pipes *f* to the brine chamber *g*. In this chamber the air comes in direct contact with brine cooled to a very low temperature, and the moisture is reduced to 1 grain per cubic foot.

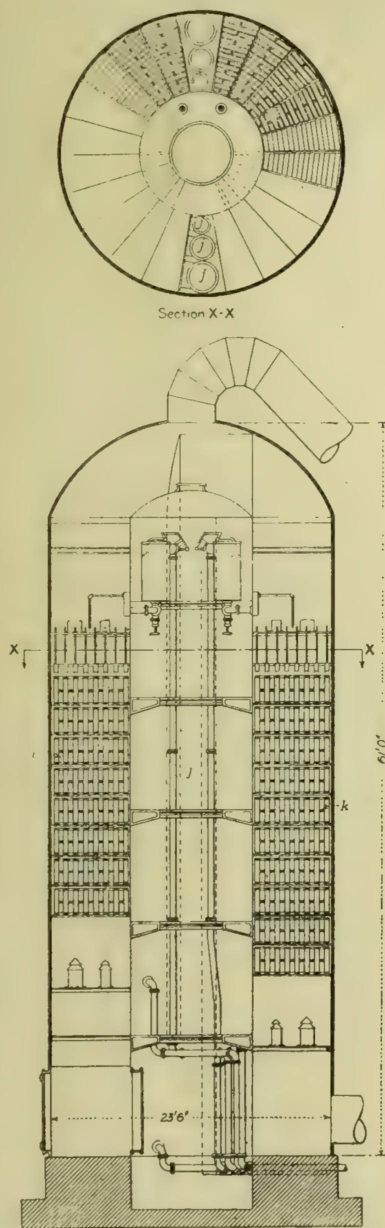


FIG. 3.—SHORT TOWER TYPE, WITH DIRECT CONTACT OF AIR WITH WATER AND BRINE. A MODIFICATION OF DESIGN SHOWN IN FIG. 2.

The air comes to the brine chamber with a practically constant amount of moisture, and by further cooling additional moisture is condensed and the brine strength is gradually weakened. The revivifying of the brine is not a difficult or expensive matter, for there is plenty of waste heat at the furnace that can be used for this purpose, and a simple apparatus has been devised by Mr. Walter to maintain the strength of the brine, which operates automatically. The centre of the tower can be used for a stairway or elevator for use of the workmen, but there is, in the nature of the operation, little to get out of order. The whole method of operation is simple and effective. The tower is built of steel plates, and the cooling fluids come in contact with metal surfaces only, as the insulation is on the outside of the tower.

The work that the fan has to do is that required to lift the air the distance from the fan discharge to the inlet of the blowing engines. The cost of installation by this method, as worked out by several engineers, is about one-half the cost necessary to install under the earlier coil-pipe system, where the moisture was deposited as snow. So the return on the investment is nearly doubled.

Fig. 3 represents a shorter tower type, designed for a medium type of furnace. This likewise operates on the direct-contact system with water and brine. The air first passes up through the water spray chamber *i*, then down through the conduits *j*, and upwardly through the brine spray chamber *k*. The space around the conduits is filled with insulating material, as the chambers on either side have different temperature conditions.

In the direct-contact system provision is made for discontinuing the use of the water spray chambers when the natural air temperature, as in the winter season, does not require its use.

In installing the dry air process a surplus of refrigerating power above the average requirements is made necessary to meet the conditions of the high humidity of the summer season, and this provides during the greater part of the year a material surplus of refrigerating capacity which can be used in other directions. This has been done successfully on a small scale at the South Chicago Works of the Illinois Steel Company, in the making of ice for use around the works. There is no reason why this cannot be carried out on a much larger scale and not only offset the cost of operating the dry-air plant, but also show an additional profit per ton of pig iron. At nearly all seasons of the year the humidity is less at night than during the day, and the night surplus of refrigerating power could be used for this purpose. Artificial ice can readily be made a by-product of the dry-air process in nearly every locality, and by-products are profitable. There is an abundant supply of condensed steam at all iron works which could be turned into ice of unquestioned purity.

DETECTION OF GAS IN MINES.

AN important subject discussed at the quarterly meeting at Cardiff of the South Wales Institute of Engineers was that of the obligation imposed by the new Mines Act of determining the average percentage of inflammable gas in a mine by taking six samples of air at intervals of not less than a fortnight. Mr. J. W. Hutchinson and Mr. Edgar Evans, of the Lewis Merthyr Collieries, contributed a joint paper on the question. They pointed out that under the Act workmen must be withdrawn if the percentage of inflammable gas is found to be $2\frac{1}{2}$ per cent. and upwards, and in a mine worked with naked lamps when the percentage is $1\frac{1}{4}$. The paper then proceeded: With this statutory limit it has become an absolute necessity that the fireman should be trained to detect the presence of low percentages by means of the safety lamp. Practically everything depended on the operator. A fireman who could not be trained to operate the flame of a safety lamp so as to detect the presence of $2\frac{1}{2}$ per cent. of gas would not in their opinion be a suitable man to occupy the position of fireman. With careful training, they held it is possible for a skilled man to detect as low as $1\frac{1}{2}$ per cent., and from analysis made at the Lewis Merthyr Collieries they had come to the conclusion that it is possible for some men to detect down to 1 per cent. Firemen have always stated the gas present in a place by the height of the cap on their lamps, but by reason of the operation of the new Act it is now necessary that they should have information as to what percentage is represented by various heights of caps. Unless this is done a number of practical firemen, who are now thoroughly acquainted with the varying condition of the roof, the timbering, and safe keeping of their districts will fail to obtain their certificates under the conditions imposed by the new Mines Act. Undoubtedly systematic analyses of the air of the mine with concomitant cap observations is the best method of training the fireman for gas testing, as he then gradually familiarises himself with the appearance of the cap for a certain percentage, and his readings in consequence become considerably more accurate. The authors said they had for a few months past, especially at one of their collieries, been training a number of firemen in the detection of low percentages of methane.

AN ARRANGEMENT FOR CASTING SMALL INGOTS.

Much has been said on the subject of using small ingots to supply merchant mills, rod mills, and tyre mills with the necessary raw material; but up to a short time ago nothing had been devised to enable manufacturers to do so. George Marton, consulting engineer, Budapesth, Hungary, claims to have solved the problem, and in an economical way, as described below. The article from which the illustrations and data are taken appeared in "Stahl und Eisen," Vol. 31, No. 47, and is written from the standpoint of the inventor.

In rolling ¼in. to ½in. rods from 2-ton to 6-ton ingots, it is pointed out that unnecessary work is done. The very expensive installation of a blooming mill is needed, for running which intelligent and high-priced labour is required; on the other hand small ingots can be cast easily and economically. In most cases, it is stated, the failure to use small ingots is only because methods now in use for ingot casting are too expensive, and not suited for large output. Works which are already equipped for casting small ingots, it is believed, will be interested in the new method, since in a small space a large quantity can be cheaply cast, the men not being exposed to undue heat and the ingots being sent hot to the rolling mills.

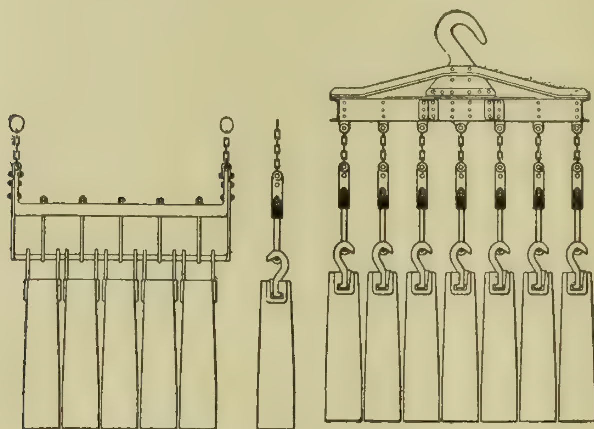


Fig. 1.—Lifting Device with Steel Hooks. Fig. 2.—Method of Using Lifting Device.

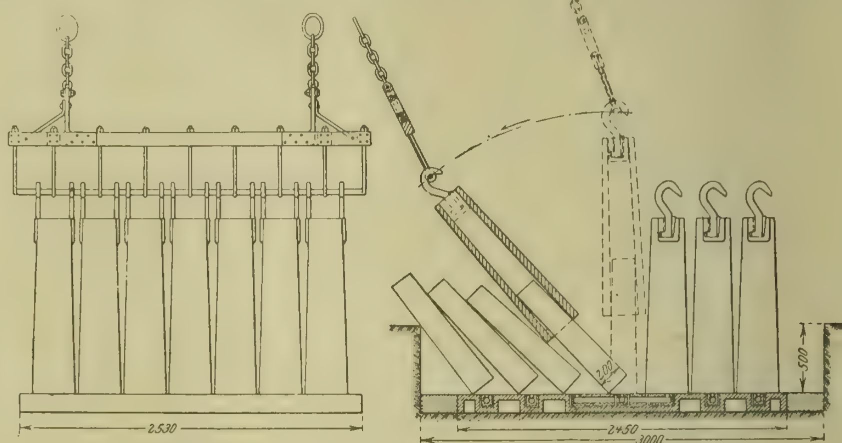


Fig. 3.—Method of Manipulation at Krompach, doing away with the Shearing Operations.

By Mr. Marton's method small ingots are bottom cast in batteries on a common bottom plate, from a common fountain. The method of casting and of removing the ingots from the runners is not much different from what is now in use, but the method of handling the moulds is entirely new. At the Krompach steel works at Resicza, Hungary, and at Falvahütte in Upper Silesia an arrangement is employed whereby several rows of moulds—in fact, all that are on one bottom plate—can be lifted from the ingots without other labour than that of the crane operator, whereas it formerly took several men to do the work from a much less convenient position.

The arrangement and operation of the lifting device are shown in Figs. 1 and 2. The hook-shaped ear of the mould is fastened into a recess on its side by means of a key, so that when the mould is scrapped the ear and key can be used again. The method of suspending the series of moulds (from five to seven in a row) makes it possible to hang them up to cool by the same crane that strips the ingots. The number of moulds which can be handled by one suspension frame depends on the size of the ingots. For example, of 8in. by 8in. ingots 49 moulds can be handled; of 5½in. by 5½in. ingots 63 moulds can be handled—in both cases including the fountain. Fig. 3 shows an arrangement in use at Krompach, where the moulds are manipulated in such a manner that after a short life the crane moves forward and throws the moulds with their ingots sidewise, thus breaking the runners. Complete batteries can be handled in this manner. It is also desirable to bring the small ingots hot to the rolling mills, to make use of their initial heat in the same manner as with large ingots. To load the ingots quickly and to keep their heat longer, the bottom plate is provided with a wall on three sides, and the ingots can be dumped into a car by a single movement.

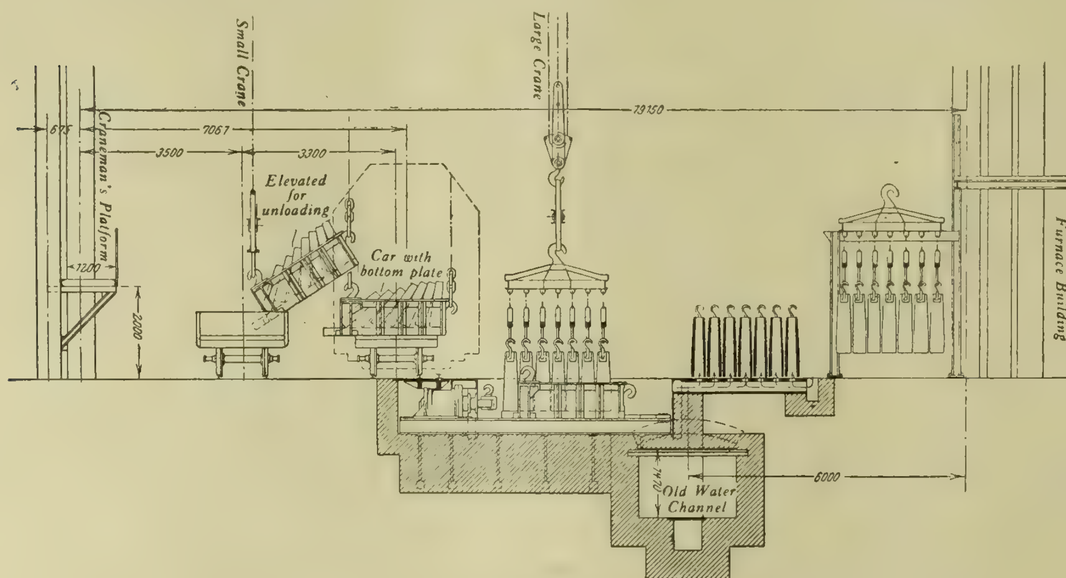


Fig. 4.—Cross-section of Casting Pit at Resicza, Austria-Hungary.

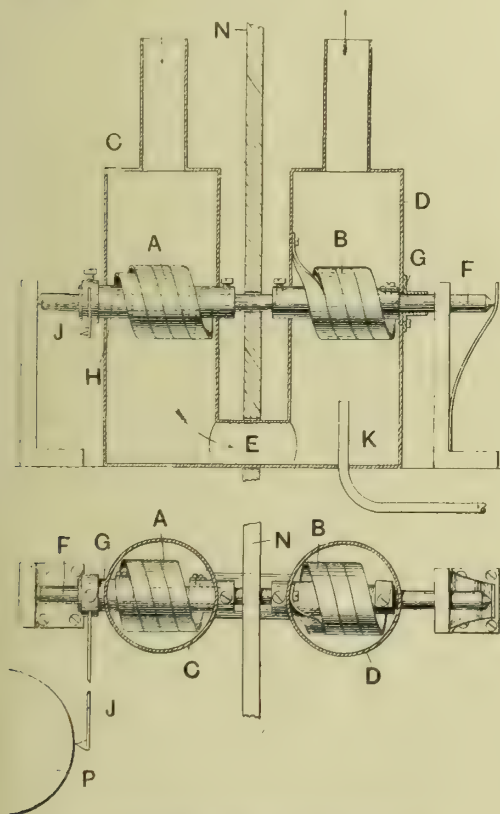
After the ingots have been brought to the rolling mills, it is best to deposit them in deep pits. These are not heated, but the ingots, on account of lying together in a large mass, keep their high temperature for several hours. They are charged by means of a crane which lifts them out of the pits. Where local conditions permit, it is preferable to bring the ingots with the bottom plate to the rolling mill and dump them directly into the soaking pits. It is suggested that the bottom plate freed from its ingots be not directly returned to the casting pit, but be placed at one side to prepare it for the next charge. By this method not only increased production can be reached, but the men who brick the bottom plates are not compelled to work in the vicinity of the hot moulds. Fig. 4 shows a cross-section of the casting pit of the steel department at Resicza.

The advantages the inventor claims for his method are summarised as follows: 1. Double the production can be reached in the same space in the pit. 2. Less labour, as a large part of the work is done mechanically. 3. The men work

under much better conditions, as they are not compelled to work near the hot ingots and moulds. 4. Order can be better preserved, as the moulds after stripping remain in regular rows in their cooling place. 5. The bottom plates suffer less, as the hot mass of steel is more rapidly removed from them. 6. The ingots are brought to the rolling mills hot; thus the output of the mill can be greatly increased and the consumption of coal and the wear on reheating furnaces greatly decreased. 7. It is possible to cast economically such small ingots as 5in. by 5½in. 150lbs. to 220lbs., the production of which in large amounts has been extremely difficult hitherto. —"The Iron Age."

AN IMPROVED DESIGN OF CALORIMETER.

A DESIGN of calorimeter which will ascertain the calorific value of a gas or other fluid under test irrespective of the temperature of the medium in which the test is made has recently been patented by the Cambridge Scientific Instrument Company, Ltd., Cambridge, in conjunction with Mr. R. S. Whipple. One construction of the instrument is illustrated herewith. It comprises two heat-sensitive units A and B composed of helically coiled bi-metallic strips. These are enclosed in flues C D respectively, the flues being connected by a duct E. One end of the helix B is held by the chimney D, while the other end is secured to a collar G moving with the shaft F. This shaft is arranged transversely of and extending through both of the flues. Similarly, the end of the helix A is secured to the shaft F and the other end is connected to a collar H which



AN IMPROVED DESIGN OF CALORIMETER.

carries an indicator or ink pen J and is free to rotate on and independently of the shaft F. This shaft is supported in bearings as shown. The instrument is applicable for ascertaining the calorific value of a gas and the latter is introduced into the flue D through a burner K connected to a gas conduit. Air supporting or aiding the combustion of the gas under test enters in the direction of the arrow through the flue C and passes through the passage E to the burner K. The products of combustion then pass over the helix B and exhaust through the chimney D.

It will be seen that the heat-sensitive elements A and B are so connected to the shaft that the expansion of one of them under the action of heat tends to neutralise the expansion of the other under a similar degree of action and to eliminate movement of the indicator J. The two elements are so adjusted that their action is equal and opposite so that with the application of an equal heating effect to both of them no movement of the pointer is produced. Thus it will be seen that the apparatus as a whole is independent of the temperature of the surrounding atmosphere and the movement of the indicator J is the result only of the heat applied to the helix B by the combustion of the gas under test at the burner K. A heat-insulating wall N is provided between the flues C and D. The ink pen or recorder is arranged to make a record of the calorific values upon paper carried on a drum P, so that a permanent and continuous record of the readings is obtained. The calorimeter is particularly applicable for testing the calorific values of gases although it is not limited to such sources of heat. In modern gas practice, however, owing to the large increase in incandescent gas lighting and the development of gas engines, and especially of gas engines operated by producer gas, the determination of the calorific value of the gas has become of very considerable importance. With the present apparatus a continuous record of the calorific value made in gas works or producer plant is obtained and this is in many cases required in order that the engineer in charge may know that a given calorific value is being constantly maintained. By this apparatus also the true calorific value may be ascertained with corrections automatically made for the temperature of the medium surrounding the source of heat.

AMERICAN STATE INSPECTION OF LOCOMOTIVE BOILERS.

G. P. ROBINSON, U.S. Assist. Chief Inspector of Locomotive Boilers, in a paper before the New England Railroad Club, gave some particulars of State inspection of locomotive boilers in America. From his observations it appears that in 1905 the State of New York passed a boiler-inspection law. Shortly afterward the State of Ohio did likewise. Then Pennsylvania started the inspection of boilers under the police powers of the State. Then the Dominion of Canada passed a law very similar to the New York and Ohio laws, and other States were preparing to pass laws. A number of Congressmen then introduced Bills, and those Bills were all boiled down, after long conferences, until we get the law of February, 1911.

The law required that the railroads file within three months of the passage of the Act their rules for boiler inspection. These rules were to be approved by the Interstate Commerce Commission. There are about 2,200 railroads in the United States engaged in interstate commerce; 170 of those roads filed rules. If you get out rules for so many railroads and 57,000 locomotives you have to have them uniform; therefore, we could not adopt the 170 rules, but the chief inspectors, co-operating with a railroad committee representing most of the roads, recommended rules which the Interstate Commerce Commission adopted on June 2nd, 1911.

The law provides for a chief inspector, two assistant chief inspectors, and 50 district inspectors. The country was divided into 50 districts, and we have an inspector in charge of each district. The inspectors make as thorough inspections as they can, which are, in fact, check inspections on the railroads, and the railroads are required to live up to the inspection rules.

The inspectors have the right to remove a locomotive from service when it does not comply with the rules, and in exercise of this right have taken out of service 2,209 locomotives, to secure proper repairs being made.

Kelvin Memorial.—A general committee representing the engineering societies of the British Empire and of the United States of America, has been formed to carry into effect a proposal for the erection in Westminster Abbey of a memorial window to the late Lord Kelvin, who was the foremost man of science of his day, and a distinguished engineer long associated with the engineering profession in the application of scientific knowledge to enterprises of world-wide importance. Subscriptions are invited to the memorial fund, which should be forwarded either to Dr. J. H. T. Tudsbery, honorary treasurer, 12, Dartmouth Street, Westminster, S.W.; or to Messrs. Coutts & Co., bankers, at 440, Strand, W.C., the treasurers to the fund.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

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Power hammer for riveting. Ramage. 14971.
Internal combustion engines. Sorg. 15141.
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Dynamometers. Heenan & Froude, Ltd., and Harrison. 15695.
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Dynamometers. Walker. 15845.
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Roller bearings. Ellis. 19446.
Indicating mechanism for height and length measuring devices. C. V. Biedenfeld & Co. Ges. 19684.
Valve tappets for internal-combustion engines. Triumph Cycle Company, and Roberts. 20214.
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Governing mechanism for elastic-fluid turbines. Warwick Machinery Company (1908). 22768.
Pressure-regulating valves. Cockburn & MacNicoll. 22846.
Sintering of fine ore material. Gayley. 23038.
Method and means for producing tubes from blanks by drifting. Ehrhardt. 23373.
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Burner apparatus for spraying liquid fuel. Middlemiss. 26575.
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Exhaust valve mechanism for central-exhaust steam engines. Hargreaves & Bruce. 1425.
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Gaseous or pulverulent fuel fittings for calcining furnaces. Bierhals. 2503.
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Apparatus for lubricating crank shafts. De Coninck. 12862.
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Terminals for electric storage batteries. Lake. 13299.
Telephone systems. Derriman. 15133.
Dynamos. Priestley & Aldred. 15390.
Electric arc lights. General Composing Company Ges. 15471.
Automatic telephone systems. Telephon Apparat. Fabrik E. Zwietusch & Co., Ges. 15569.
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Volt registering devices. Barker. 217.
Interrupter for electric ignition of internal combustion engines. Bloxham. 4699.
Sparking plugs. Harber. 6162.
Ignition devices for internal combustion engines. Brenot. 6567.
Electric arc lights. General Composing Company Ges. 8907.

METAL QUOTATIONS.

TUESDAY, JULY 23RD.

Aluminium ingot	75/- per cwt.
" wire, according to sizes, &c. ......from	102/- "
" sheets " " ...... "	120/- "
Antimony .... £27/10/- to	£28/-/- per ton.
Brass, rolled	9¼d. per lb.
" tubes (brazed)	11¾d. "
" " (solid drawn)	10d. "
" " wire	9¼d. "
Copper, Standard	£78/15/- per ton.
Iron, Cleveland	57/- "
" Scotch	63/9 "
Lead, English	£19/-/- "
" Foreign (soft)	£18/10/- "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£8/10/- per bottle
Silver	27⅞d. per oz.
Spelter	£26/-/- per ton.
Tin, block	£199/5/- "
Tin plates	14/7½ "
Zinc sheets (Silesian)	£29/5/- "
" (Stettin; Vieille Montagne)	£29/7/6 "

THE WORLD'S SHIPPING LOSS.

THE "statistical summary" of Lloyd's Register, of vessels (100 tons and upwards) of all nations totally lost, condemned, &c., for the past year gives us a good idea of the vastness of the shipping of the world, and of the loss that is continually taking place. The gross reduction of the effective tonnage of the mercantile marine of the world was last year 884,843 tons, steam and sail. Though these vessels lost are for the whole of the maritime nations they are so in different degrees, for the United Kingdom is far ahead of other nations as an owner of shipping. Dealing only with the steamships it may be said that the three chief steamship-owning nations and the quantity of steam tonnage that they own, are as under:—

	Gross tons.
United Kingdom	17,292,000
Germany	4,092,000
United States	1,715,000

Further, the United Kingdom has an interest in the steamships owned by her colonies, which have in the aggregate a tonnage of 1,350,000 tons. Though the loss of British shipping is naturally the greatest, it is satisfactory to note that the proportionate loss is not the greatest. The United Kingdom had for the past year a loss at the rate of 1·08 per cent. of the total steam tonnage that it owns; in sailing vessels, the British loss was at the rate of 4·03 per cent., whilst amongst foreign nations it rose to as high as 9·15 per cent. on the part of Sweden.



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Edited by
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Canada as a Market for Engineering Products.

It was Sir Wilfrid Laurier, we believe, who described Canada as the Twentieth Century Land. The phrase has stuck, and not merely because there is about it a glamour and an optimism which appeal to Canadians, but because the outside world recognises that there is at least a possibility that the prophecy may come true, and recognising this is discussing Canada and Canadian business with very great earnestness. This country has often been blamed for its lukewarm attitude towards the Canadian market, but there are evidences that this reproach may soon pass. Certainly the last year or two has witnessed the flow of a good deal of British capital into Canadian businesses and investments, and also an increase in the number of British firms having representatives or agents in Canada. Finally, the scheme for a Canadian Navy has been the cause of several British firms of shipbuilders making arrangements to establish shipbuilding yards in Canada. These influences, strengthened by a persistent and skilful emigration policy on the part of the Canadian Government, have brought the possibilities of the Canadian market well within the realm of practical politics. Engineers are not least interested in the Canadian market, because a new country like Canada naturally requires a great deal of machinery and is scarcely in a position to supply most of it from its own factories. Turning then to the Canadian market for engineering products, it is necessary firstly to realise that the Canadian market is not all one. Even in this country the market is not quite all one, and geographical and other conditions make it more difficult for a firm to obtain a footing in one part of the country than in another. Canada is so much bigger than this country and the conditions holding in one part so often different from those in another that English firms contemplating entering the Canadian market should divide it into sections and select, at least for the first attack, the likeliest section or two and devote their energies to these alone. For general purposes Canada may be divided into four sections. On the extreme East there are the Maritime Provinces of Nova Scotia,

with Prince Edward Island, New Brunswick, and Quebec. Newfoundland is politically a separate country and in many trade respects stands alone also. Stretching from Quebec to the prairies is Ontario, sometimes known as the Middle-West, although the title is variously applied. From Ontario to the Rocky Mountains is almost unbroken prairie containing the provinces of Manitoba, Saskatchewan, and Alberta. West of Alberta is British Columbia, extending to the Pacific Ocean and mostly mountainous. North of these four divisions extend the North-West Territories and the Yukon, but except for the goldfields of the Yukon the British engineer need not at present trouble about Northern Canada.

These four divisions of Canada correspond roughly with four great market territories. These markets are determined, from the British engineer's point of view, not only by their distance from this country and by the general character of their industries, but also by the nearness or otherwise of our American competitors. The United States lies to the south of the Canadian markets, but on the Atlantic coast the geography is such as to place all but the nearer American States at some distance from the Maritime Provinces of Canada. On the other hand, Ontario, except the extreme eastern portion, is favourably situated from the American engineer's point of view. The chief engineering works of the States are situated in the Northern States south of Ontario. The whole of Canada is largely agricultural and hence the demand for engineering products is largely for agricultural implements and farm machinery. Leaving these for the moment, the Maritime Provinces contain several mines and one or two iron and steel works of note. Moreover, an extension of the shipbuilding industry seems certain in the near future. Most of this market is quite accessible from this country, the sea voyage of 3,000 miles not being a very expensive matter. Moreover, it is very convenient for sending a representative over or conducting a correspondence, both matters which count a good deal and, indeed, often turn the scales decisively. In many respects, therefore, the Maritime Provinces and the extreme easterly portion of Ontario constitute a good market for British engineers to attack. Ontario makes a good market because it already contains many large and prosperous industries, including iron and steel works, and promises to develop further along these lines. Also it is moderately accessible from this country. On the other hand, our American competitors are on the doorstep and often possess some financial interest in the Canadian businesses they make quotations to. There is also what we may call the general American influence, which we shall consider later. The Ontario market thus requires more judicious consideration before being attacked than does the Eastern market. The Prairie market naturally calls mainly for agricultural machinery and such machinery as one finds in electric lighting, water supply, and sewage works in small towns. The Prairie market is the most difficult for British firms to handle, but if it can be successfully catered for it promises excellent returns. Labour is scarce and every farmer employs machinery as fully as he can afford to. Gasolene ploughs, threshing machines, and wind-motor pumps are very common. In the towns, too, a surprising amount of machinery is used. All but the very smallest railway stations have one or more grain elevators. Thus, taking the Edmonton branch line from Calgary, in Alberta, the last of the prairie provinces, the first six towns had populations (in 1911) of 300, 350, 700, 1,000, 1,050, and 300, and the numbers of grain elevators were respectively two, three, five, four, three, and one. Similarly, all but one of the six towns (!) possessed a telephone service and five had their own newspapers. Probably by this time the sixth has fallen into line in each case. When a town attains to the dignity of a thousand inhabitants it calls out for electric lighting plant, and usually is not long before it gets it. For this market standardised and cheap articles are necessary if success is to be obtained, and in this type our American rivals are experienced. Although the Prairie Provinces are mainly agricultural, there are of course other industries, especially at Winnipeg, Medicine Hat, Calgary, and Lethbridge, whilst in Alberta there is promise of considerable coal mining. British Columbia approaches most nearly to England in its climatic conditions and social habits. Also, where time is not important, freight favours British engineers against the Americans, but where time is important goods have to be transhipped at the Atlantic seaboard and sent overland by rail, which adds greatly to the cost. British Columbia agriculture is concerned largely with fruit growing and calls for relatively little machinery, except a few simple farm implements. On the other hand, the mineral wealth of the province is very great, as are also the timber resources, and these two fields are now being steadily developed, so that there is a considerable market for moderately heavy engineering as well as for general appliances. Where stocks can be carried, sea freights only need be paid and costs kept down. Apart from the special requirements of the various markets some general considerations may be noted. The protectionist policies of both Canada and the United States give us an advantage over both countries as regards labour charges and other manufacturing costs. As against this we have, of course, to meet the tariff wall, which, however, is higher against the United States than against this country, and owing to the facts that Canada is largely agricultural and is developing so rapidly she must for some time to come buy machinery very largely abroad. Hence there should certainly be a market for British products in some of the provinces. On the other hand, it is important to bear in mind that in many departments of engineering American machinery and appliances differ considerably from British. Canada is both geographically and economically very similarly situated to the United States, and hence American machinery tends to be well suited to Canadian conditions. Moreover, Canada is literally teeming with Americans and the whole country is permeated with American industrial ideas and flooded with their technical literature. British engineers who covet the Canadian market must bear this in mind, and where American practice differs from ours it will often be necessary to find out just what the Canadian prefers and then to make it. The Canadian is less likely than any other nationality to accept what is offered unless it happens to be what he wants. Canada is a white man's country. It is primarily an agricultural country, but it has also immense mineral and industrial resources. These will undoubtedly be developed—indeed are being developed—and there are openings in Canada for new works and factories. Already several British firms have arranged to build works or to take a technical and commercial interest in Canadian firms, and these are developments which should be carefully studied. There are more ways of benefiting from a great and expanding market than by setting up an agency, and these other ways should not be ignored.

Motor Mail Vans.—The postal authorities have decided to replace the horse mail now used for town purposes by specially-constructed motors, while heavier vehicles of a similar type are being prepared for the carriage of mails between the Metropolis and many important towns in the home counties. By way of experiment, capacious vans have been running between St. Martin's-le-Grand and Brighton for some time past, and so successfully that 100 new vehicles are ready for use in other districts. They will be kept going day and night, and are expected to cover something like a million miles per year.

THE SECOND LAW OF THERMODYNAMICS.*

BY CHARLES P. STEINMETZ, CHIEF CONSULTING ENGINEER, GENERAL ELECTRIC COMPANY.

THE second law of thermodynamics may be expressed in the form: "In any cyclic process, the sum total of unavailable heat energy increases." Thus, if we transform electrical to mechanical energy and backwards, we do not get back the total amount of energy, but some of it is converted into heat. Of this heat energy at least a part can never be re-transformed into any other form of energy, *i.e.*, it has become unavailable. Or the law may be expressed, "Without expenditure of some other form of energy, heat flows only from higher to lower temperature"; that is, from a higher heat level to a lower heat level. In this form the law is easiest to grasp; just as water, without expenditure of outside energy, flows only from higher to lower level.

The result thereof is that the total heat energy can never be used in any case: but that amount which is still heat energy when the lowest heat level or temperature has been reached cannot be transformed except by the use of additional energy, *i.e.*, it has become unavailable. Thus, of the total heat energy in the superheated steam issuing from the boiler, only that corresponding to the temperature range from admission temperature to the temperature of surrounding space can be used; but the much larger amount of heat energy which is still contained in the steam exhausting into the condenser at atmospheric temperature is unavailable.

To some extent availability is relative. The heat energy in the steam exhausting into the condenser at atmospheric temperature, which is unavailable under ordinary conditions, would be available in part if we could exhaust at the temperature of liquid air; and of the heat energy remaining in the exhaust at liquid air temperature, a further part could be transformed by exhausting at the temperature of liquid hydrogen, &c. Even between the limits of atmospheric temperature appreciable variations of available energy, and with it differences in the efficiency of steam turbines, &c., are noticeable. However, the total heat energy could be made available only by dropping down to the absolute zero of temperature, and as this cannot exist, all the energy, which is still heat energy at the minimum temperature of the universe, has become absolutely unavailable, *i.e.*, it can never be used without the expenditure of some other form of energy.

An analogy is given by water power. Of the energy of a watercourse, only that represented by the difference in height between the upper level and the lower level is available at the point of development. However, some miles distant, a still lower level may exist, and further hydraulic energy made available by it; but finally the ocean level is reached. Here the water still contains an enormous amount of gravitational energy—that corresponding to its distance from the centre of the earth. This, however, is now absolutely unavailable, since no lower level exists into which the water can be discharged, and outside energy would have to be expended to make such a lower level.

The result of this functioning of the second law of thermodynamics is that the temperature crests in the universe are levelled off, the temperature valleys filled up, the amount of unavailable heat energy—that below the bottom of the temperature valleys—is increased; in other words, the temperature of the universe tends towards a uniformity, at which all the heat energy has become unavailable. The temperature differences in the universe are thus maintained only through the expenditure of other forms of energy, and other energy is thus continuously poured into the gulf of heat energy in producing available heat energy through temperature differences, which again are continuously levelled off and the heat energy made unavailable by the functioning of the second law of thermodynamics: but no return path exists from the unavailable heat energy to other forms of energy.

The outcome of this unidirectional transformation law must be that finally all the other forms of energy will have been converted into heat energy, and all the heat energy have assumed a uniform temperature level, *i.e.*, become unavailable. This means that all the energy of the universe must finally be converted to unavailable heat energy, and if the second law of thermodynamics holds universally, no return exists from this state; hence, the universe must finally run down, just like a clock. All energy transformation will stop, *i.e.*, all motion will cease, and the universe will be dead. The energy will still be there—the law of conservation of energy will not have been offended—but as unavailable heat the energy will be dead. It is true that if we define energy as that entity which can do work, it is questionable whether the unavailable heat energy of the dead universe, which can never do any work, can still correctly be called energy.

The second law of thermodynamics is well founded on our experience. The reasoning from this law as to the death of the universe is logical. At the same time, the conclusion that the universe must run down is not reasonable. If the universe is eternal, has existed since infinite time, then it should have run down an infinite time ago. But if it is not eternal, but had a beginning, what was before? How could energy begin without offending the first law, that of the conservation of energy? Thus, in the final reasoning, we arrive at a contradiction.

The explanation may be either that we have attempted to reason beyond the limits of the capacity of the human mind, which, being finite, always fails in the attempt to reason into the infinite, or it may be that the second law of thermodynamics is not of universal application, is not a general law of Nature, but is of limited application only. In the following pages I wish to show that the latter is the case. A single exception obviously would be sufficient to show that the second law of thermodynamics is not a universal law, and that the conclusions regarding the death of the world, based on this law, are thus not justified. As the thermodynamics of gases is far simpler and more completely known than any other branch of thermodynamics, it would offer the most promising field of study.

The kinetic theory of gases is probably as fully and conclusively proven as anything can be by the inductive method of science. According to this theory, the heat energy of a gas is the mechanical energy of the irregular molecular motion: The $\frac{1}{2} m v^2$ of the molecules and the atoms in the molecules. The second law of thermodynamics, then, is nothing but the application — the natural consequence of the operation—of the law of probability. If we bring together two gases of different kinetic molecular energy, *i.e.*, of different temperature, such as a litre of air at 30° C., and a litre of air at 10° C., in such a way that the molecules can exchange their motion, *i.e.*, heat can flow between the gases, it is obvious that, in an interchange of velocity between the molecules, one having a velocity above the average is more likely to lose than to gain velocity; a molecule with less than average velocity is more likely to gain than to lose velocity. The result of the interchange of velocity—or rather of kinetic energy, in accordance with the laws existing between bodies, probably the law of gravitation—thus is an averaging of the kinetic energy, *i.e.*, an equalisation of the temperature—in the above instance to 20° C. for both litres of air. However, the result of the operation of the law of probability cannot be a perfect equalisation of the molecular energies so that all the molecules have exactly the same energy, but sometimes a fast molecule may still gain energy—although it is more probable to lose—or a slow molecule may lose. The result thus would be a distribution of the kinetic energies between all the molecules in accordance with the probability law; and the temperature then represents, or is, the average kinetic energy of the molecules—is represented by an average molecular velocity. This is the velocity found most frequently amongst the molecules; but all higher and lower velocities exist, becoming, however, more and more rare the further they differ from the average velocity, in accordance with the probability law.

Causing heat to flow from a lower to a higher temperature, then, means separating the faster from the slower molecules. Experience, expressed by the second law of thermodynamics, says that this can be done only by the expenditure of outside

* From the "General Electric Review," Schenectady.

energy. However, such a separation of the fast from the slow molecules without expenditure of outside energy would in no way contradict the law of conservation of energy, as Maxwell has shown. Assume that we have a volume of gas at constant temperature—the two litres of air at 20° C. resulting from the previous illustration—and have a partition to divide the gas volume in two parts. This partition may be perforated by numerous minute doors, which we asume to have no weight and to move without friction, so that no energy is required to open and close them. Assume now that at every such door we place a demon, who opens the door whenever a fast molecule comes from the right, or a slow molecule from the left, and lets this molecule through; but does not open the door for a slow molecule from the right or a fast molecule from the left. The result would then be that gradually the fast molecules would accumulate in the left, and the slow molecules in the right section of the space; that is, without expenditure of outside energy, but through the intelligence of the demons, heat energy would flow from the lower temperature on the right to the higher temperature on the left side of the partition, against the second law of thermodynamics.

Now these demons exist in Nature. Every cosmic body is such a demon, and separates the fast from the slow molecules, keeping the latter and sending the former out into space, and thereby causing heat energy to flow into space at a temperature far above its own temperature. Consider, for instance, our earth. In the uppermost regions of the atmosphere, assume a molecule which happens to be moving in an upward direction, and does not happen to approach another molecule so closely that its direction of motion is changed. Such a molecule will move upwards, until its motion is stopped by the force of gravity, by the attraction of the earth, when it falls back again. If, however, the upward velocity of the molecule is sufficiently high—above a certain critical value—then this molecule escapes from the attraction of the earth into space, and never comes back. This critical velocity at which a molecule escapes from the earth is 11,000 m. per second. Assuming the average velocity of the molecules of the air, corresponding to an average terrestrial temperature of 10° C., or 283° absolute, as 750 m. per second, then the velocity of 11,000 metre-seconds corresponds to a temperature of $283 \times \left(\frac{11,000}{750}\right)^2 = 60,000°$ C. That is, the molecules which the earth sends out into the universe have a kinetic energy corresponding to a temperature of 60,000° C.; or, as we may say, by the escape of these molecules heat energy flows from the temperature of the earth, 10° C., into a temperature of 60,000° C.

This brings up an interesting feature. Since the temperature of the earth steadily decreases with increasing altitude, we usually think of cosmic space as extremely cold—near the absolute zero of temperature. Empty space obviously has no temperature, since temperature is an attribute of the matter in space. Judging the temperature of cosmic space by the kinetic energy of the molecules which have escaped into space from the larger cosmic bodies and which traverse space in irregular motions, we would be led to the conclusion that, far from being extremely low, it would on the contrary be of an inconceivably high value, probably several hundred thousand degrees centigrade. This conclusion would better agree also with the very simple line spectra of gaseous matter in space, as shown by the nebulæ.

We may ask, however, whether the kinetic energy of a molecule which, due to its high velocity, has escaped into cosmic space, can still be considered as heat energy. Heat energy is the kinetic energy of irregular molecular motion. The difference between the heat energy of a gas and mechanical energy thus lies in the irregularity of the motion and the size of the moving particles, which is such that only the resultant effect of the mechanical motions of large numbers of moving particles can be perceived. Irregularity of motion, however, is relative; for if we consider a single molecule which has escaped into space by reason of its high velocity, we cannot attribute any irregularity to its motion. That is to say, its kinetic energy cannot further be considered as heat energy; but the kinetic energy of the molecule, which was heat energy while the molecule moved in a mass of gas together with other molecules, is mechanical energy of cosmic motion, and the molecule is a cosmic body traversing space under the laws of gravitation, but not subject any more to the law of probability of mass action, *i.e.*, to the second law of thermodynamics.

This brings us to the question of the limitation of the conception of heat energy, but for this purpose we do not need to go to cosmic space. If we consider the vacuum tube, and go to the highest vacua—the cathode ray vacuum and beyond—the distances between the molecules become so large that the free path of each molecule becomes appreciable, and the action of the kinetic energy of the individual molecule becomes noticeable. But as soon as this is the case, the kinetic energy of the molecule cannot well be considered as heat energy any more, and the laws of thermodynamics, which, after all, are the laws of probability of a mass of moving bodies, begin to fail in their application. Thus Crookes proposed to recognise this condition of a high vacuum, where the molecules act as individuals, as a fourth state of matter. This again throws a sidelight on the question of the temperature of the cathode ray tube, or the mercury arc, in a vacuum. At these very high vacua we may say that we cannot speak of a temperature at all, and heat energy, as the resultant mechanical energy of molecular motion, ceases to exist with the separation of the molecules to such distances that their resultant effect vanishes when compared with their individual actions. When, however, the kinetic molecular energy ceases to be heat energy, the second law of thermodynamics, which is the application of the law of probability, also ceases.

Spontaneously, heat energy flows from a higher to a lower temperature, until equality of temperature is reached, and most methods of temperature measurements are based on this law. However, even this law is correct only within certain limitations. For instance, in the atmosphere of our earth, where there is continuous interchange of heat energy and the air is never at rest, nevertheless no equalisation of temperature occurs, and there is no tendency to a condition of equilibrium at constant and uniform temperature—the condition of equilibrium is a definite and very decided decrease of temperature with increase of altitude. If we assume that no heat energy is supplied to or withdrawn from our atmosphere, and that the atmosphere is very thoroughly mixed so as to reach equilibrium condition, then—if for a moment we leave out of consideration the effect of condensation of moisture—the equilibrium condition would be a uniform decrease of temperature with increasing altitude, down to the absolute zero of temperature at an altitude of about 29 km. (about 18 miles). As function of the altitude, the theoretical equilibrium condition of temperature, air pressure, and air density, assuming 10° C. as surface temperature. The reason for this is obvious. In the equalisation of temperature, whether by the molecules in bulk, in air currents, or by the motion of individual molecules in heat conduction, any upward motion of a molecule is accompanied by a retardation due to the attraction of the earth, and thereby a decrease of kinetic molecular energy, *i.e.*, of temperature. Any downward motion is accompanied by an acceleration by gravity, and consequently by an increase of kinetic molecular energy and therefore of temperature, and equality of temperature throughout the entire atmosphere is thus impossible with freely moving molecules; the theoretical condition of equilibrium is the temperature distribution with the altitude, in accordance with the adiabatic law.

In accordance with this theoretical law of atmospheric equilibrium, the atmosphere would have a finite limit at about 29,000 m., at which limit air pressure, density, and temperature fall to zero. We know, however, that an appreciable atmosphere extends very far beyond these limits, and for the upper regions of the atmosphere this theoretical law of equilibrium thus fails. However, this equilibrium condition is based on thermodynamic relations, *i.e.*, is that corresponding to the average velocity of the air molecules. The molecules which have a higher velocity than the average corresponding to the temperature are capable of reaching up to correspondingly higher altitudes—beyond those that would limit the extent of the atmosphere if all its molecules had the same average velocity. Thus, even in our own atmosphere,

and without going beyond it into cosmic space, the law of gravitation is doing the work of Maxwell's demons in separating the faster and the slower molecules, and collecting the former in the higher regions of the atmosphere. Thus the second law of thermodynamics does not apply to the atmosphere of the earth, since kinetic molecular energy is transferred from the regions of lower molecular energy to the regions of higher energy; that is, heat energy flows from lower to higher temperature, or, rather, flows against the thermodynamic temperature equilibrium. Furthermore, this phenomenon is not beyond the limits of heat energy—that is, in the range where the molecules act as separate masses—and their kinetic energy thus is not heat energy but mechanical energy. In the present case, however, the phenomenon applies to the resultant kinetic molecular energy, that is, to the temperature. The average kinetic energy, and thus the temperature of the upper regions of the atmosphere, must be higher than that which corresponds to the theoretical thermodynamic equilibrium.

Thus we are led to the conclusion that the second law of thermodynamics is not a universal law of Nature, but applies only within the limited range of thermodynamic engines from which it has been derived. It does not apply to the universe as a whole; and the conclusions derived from it, that the universe must finally come to a standstill, are not justified.

ELECTRIC FURNACE FOR NON-FERROUS METALS.

AN electric furnace for melting brass, drosses, scrap metals, and other non-ferrous metals and alloys which is novel in design, as it is a combination of the arc and resistance types, has been developed by the Pittsburg Electric Furnace Company, Pittsburg. The furnace is the invention of R. S. Wile, general manager of this company. The original furnace was of the stationary type and was used for smelting tin drosses. A tilting furnace also is built which embodies the same principles of operation as the stationary melting medium. The tilting furnace is illustrated in Fig. 1.

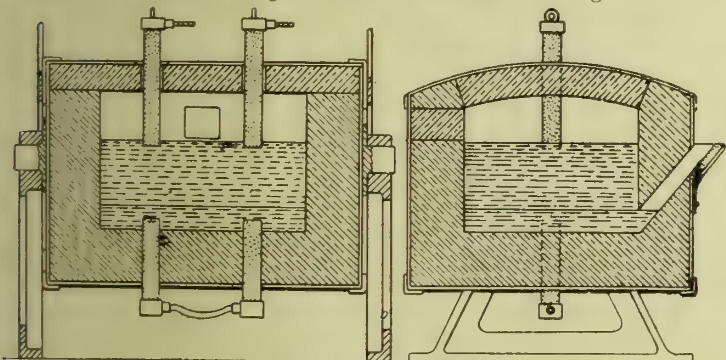


FIG. 1.—SECTIONAL VIEWS OF ELECTRIC FURNACE FOR NON-FERROUS METALS.

Four carbon electrodes are used, two extending through the bottom of the furnace and the other two entering through the top. When preparing to make a heat, the furnace is partially filled with broken glass and the carbon electrodes are arranged so that they almost come in contact with each other. An arc is thus formed, which soon melts the glass surrounding it. The glass in its molten state becomes a conductor of the electric current, notwithstanding the fact that previous to melting it is a non-conductor. After the glass has been melted the electrodes are drawn apart and the current passes through the entire glass bath, heating it to a high temperature, the glass becoming exceedingly fluid. The electrodes then are moved farther apart and the glass is maintained in a fluid condition. By this means all the resistance offered to the passage of the current by the glass serves to heat it and to maintain it in a molten state. Until the glass is in this fluid condition no metal is charged into the furnace.

When the glass bath has reached a high temperature the metal is charged, and, owing to the difference in specific gravities and the fluidity of the glass, the metal sinks to the bottom of the furnace. The glass serves in addition as a covering and completely protects the metal from oxidation, thereby reducing the loss to a minimum. The glass is the resistance material for heating the charge and also protects the metal. Any kind of scrap glass can be employed, broken bottles, window glass, &c., being equally effective. Nor is it necessary to make a new charge of glass every time a heat is tapped. Tests have proved that the glass can be used for several months of continuous work and when a new charge of glass is to be made, the molten glass is poured from the tilting furnace or is tapped out of the stationary furnace.

At Connellsville, Pa., two stationary furnaces have been installed for melting tin drosses and slags. This type of furnace is recommended for large melts, but for small heats the tilting furnace has proved exceedingly advantageous. The stationary furnace is built of firebrick, but it is essential to have a highly refractory lining to withstand the high temperature and corrosive action of the molten glass and metal. Chrome brick has given the best results. This brick is not only refractory and non-corrosive, but it also successfully withstands sudden changes of temperature. This is a feature of importance in the intermittent use of the furnace, as the repeated cooling and heating cause the brick to crack. The electric current used may be either direct or alternating, 110 or 220 volts. At 220 volts the charge of glass melts more rapidly at the beginning of a heat, but after the melting has begun the 110 volt current gives practically as good results. Carbon electrodes are used.

The tilting furnace is equipped with the same melting arrangement as the stationary furnace, with the exception that it is arranged to tilt to permit of easy pouring. For smelting drosses, scrap metals, &c., the stationary furnace gives excellent results, owing to the large quantities that are to be treated. The tap hole is plugged with an iron bar, and when the melting operation is completed the bar is pulled out. The stationary furnaces are constructed in sizes up to 20 tons capacity, while the tilting types are made in various sizes up to 1,000lbs. a charge. If the voltage of the current is sufficient two furnaces may be connected in series and a corresponding economy in current may be obtained. The temperature of the molten glass may be increased to 5,500° Fah., if necessary, without injury to the lining.

A furnace melting a charge of 200lbs. of brass will consume approximately 22 kw. of current at 100 volts. By connecting two furnaces in series a higher voltage may be employed or the current can be cut down by a rheostat; if necessary, a larger furnace can be used. From a 200lbs. furnace a heat of this size can be poured in 30 minutes. A 500lbs. furnace consumes 32 kw. and a 1,000lbs. furnace will melt a ton of brass every hour and if run continuously will consume about 68 kw. in melting.

As the metals are constantly covered with the molten glass, the losses from oxidation are exceedingly low. In melting dirty brass scrap, such as sweepings and grindings, the loss has been kept as low as 1¼ per cent. This is based on the estimated amount of actual metal in the scrap. The loss on new metals has been as low as 0·33 per cent.

Large Hydro-electric Generators.—The "Electric Review and Western Electrician" gives some particulars of a large hydro-electric generating unit which is to be installed in a station at Keokuk on the Mississippi. The station will have an ultimate capacity of 300,000 h.p. and energy will be supplied at 110,000 volts to St. Louis, a distance of 135 miles, as well as to other neighbouring towns. Each turbine and generator will form an independent unit. Each wheel, mounted on a vertical shaft 25in. diam. in a spiral chamber, 21ft. 3in. diam., and moulded in the concrete substructure, will operate at a constant speed of 57·7 revs. per minute and will have a normal capacity of 10,000 h.p. The generators are to be installed on top of the wheel pits directly over the turbines and will be direct-connected to the vertical wheel shafts by forged steel flanged couplings. Three-phase current will be generated at 11,000 volts. Direct-current excitation for these generators will be supplied by 100 kw. motor-generator sets, for which the operating current will be secured from a 2,000 kw. alternating-current waterwheel-driven generator. Eight water-cooled 110,000-volt transformers will be installed for stepping up the voltage of the current for distribution over the high-tension transmission lines of the company to distant points. The rotors of the generators operating at low speed account in a measure for the great size of the machines for their rated capacity. The generators measure 32ft. diam. by 12ft. high, and the total weight of each machine is nearly 300 tons.

MANUFACTURE AND TREATMENT OF STEEL FOR GUNS.*

BY GENERAL L. CUBILLO.

(*Concluded from page 111.*)

Heat Treatment.—Before proceeding further, it will be convenient to consider, at this point, the heat treatment most appropriate for gun steel. The steel, having been cast in a mould of truncated cone shape, requires, of course, to be forged, in order to give to the gun or part of the gun the required form, which is always that of either a hollow or a solid cylinder, of varying length, with different diameters outside, and sometimes also inside. The annealing after the forging, the hardening—or hardenings, if it is necessary to harden more than once—and the subsequent tempering or temperings, constitute the series of heat treatment processes given to the steel for gun construction. Forging is not only necessary for giving the required form, but principally to change the crystalline structure of the large and medium-sized castings into one of finer grain, almost amorphous, which is essential for the best development of the physical and mechanical properties of a given steel for ordnance purposes. But as it is possible to obtain from a given steel, simply by heat treatment, without the aid of the press or of the hammer, physical and mechanical properties equal to those conferred by forging, it is only natural to ask if the forge is absolutely necessary, and whether, instead of casting ingots of the usual shape, it would not be possible to cast pieces of approximately the final form, and subject them afterwards to the heat treatment capable of modifying the texture developed by the cooling after the casting. This is a question which has been very much discussed for many years, and opinion seems, on theoretical grounds, to be in favour of the suppression of the forge, but on practical grounds the forge is retained, and there is no indication whatever that it is likely to be dispensed with.

The manner of fixing the amorphous structure obtained by heat treatment is to cool the piece very quickly. For thirty or more years these facts appear well established, yet the specifications of all the armies and navies of the world continue to require the use of the forge in the manufacture of gun steel, notwithstanding that eminent metallurgists have demonstrated the possibility of making very good pieces for gun construction without the aid of the forge. The tests were certainly made with small pieces many years ago, but an enterprising firm in Sweden now makes guns up to 24 centimetres calibre without forging. In 1882 Mr. Pourcel, in a paper read before the Iron and Steel Institute, described the series of operations which constituted the whole process at the Terre-Noire Steel Works in the manufacture of steel hoops for 4in. guns. These hoops must, of course, satisfy the same specifications as those required for the forged metal. After casting the steel with the necessary additions of ferro-silicon for freeing the ingots from cavities and securing a perfectly sound metal, a heat treatment was given to the hoops, which consisted in heating them to a yellow heat and hardening them in an oil bath of fixed weight. After being cooled in the liquid they were afterwards reheated to a temperature which varied from light cherry-red to a dark cherry-red, in accordance with the chemical composition of the metal. The hoop was then cooled in a bath of the same liquid, where it remained until it was perfectly cool. By the first hardening the crystalline grain of the metal was transformed into a finer and homogeneous grain. The second hardening confers on the pieces the molecular equilibrium corresponding to their chemical composition.

The result of these two operations was a true hardening, inasmuch as the piece was heated to a higher temperature than that of the transformation point, and by this the size of the original grain was changed, and the new structure fixed by subsequent cooling in a large quantity of oil.

The second heat treatment, also called hardening by Mr. Pourcel, was, rather than a hardening or annealing, a true tempering, which caused the disappearance of the strains originated by the hardening, and increased the ductility, which had been lowered by the first operation. Sometimes it was necessary to repeat the two operations, if the tenacity of the metal was less than that required by the specifications, or only the second if the ductility obtained was less than required. Mr. Pourcel had some doubts at that time if this process, applied to guns of a calibre larger than that of 4in., would give the same excellent results. His conviction inclined him to take the affirmative side of the question. Undoubtedly he had thought the subject out in a logical manner, and it is not easy to understand why such ideas as these, so well grounded, have not been adopted by metallurgists. The Swedish Steel Works, the Aktiebolaget Bofors Gullspang, for many years has been successfully applying steel as cast to the construction of guns. Working systematically, and passing gradually from the simple to the complex, they began by producing field guns, followed by the fortress guns, and finally essayed the manufacture of coast and navy guns, commencing with a quick-firing gun of 15 centimetres in calibre. The United States of America even used a gun of this type, the trials of which were commenced in 1902, and gave exceedingly good results.

* Paper read before the Iron and Steel Institute.

Recently the author has ascertained that the Bofors Steel Works has constructed guns of 21 and 24 centimetres, whose elements have been simply cast and afterwards subjected to heat treatment. Of course, the elements for the field and fortress guns are also subjected to proper heat treatment. These are facts the importance of which it is impossible to deny. They afford evident proof of great advance in the way of applying heat treatment alone without forging the elements of guns. The author thinks, however, that it is no easy matter to cast 10in. and 12in. gun tubes 50 calibres in length, moulding them in a refractory mould.

There is another reason against the acceptance by Governments of this process of manufacture. It may happen that, despite all the precaution and care taken in the finish and casting of the elements in order to obtain pieces absolutely free from cavities, a cavity may occur in the thickness of a tube without being detected during the mechanical work, and may cause the bursting of the gun when firing.

Hardening and Tempering.—If forging is necessary, or presumably necessary, in order to obtain first-rate elements for the manufacture of the guns, the hardening process is also necessary for the tempering.

To obtain these properties in the highest degree must be the supreme object of the metallurgist. The author, during many years' experience in the manufacture of steel, both by the crucible and open-hearth processes, for 24-centimetre guns of 45 calibres in length, has found that however well conducted the forging, the transformation of the crystalline structure into one of amorphous, or fine grain, is only obtained in the highest degree (if the forging is not completed) by hardening and tempering, and sometimes more than one and more even than two such operations. As it is not the chief aim of the hardening (in semi-hard steel of the type used for gun construction) really to harden the metal, and as it is easy to obtain the required mechanical qualities by forging only (followed by an annealing), it would seem that the hardening might be dispensed with. However, as many years ago hardening in oil was introduced with excellent results, the process was retained and formed part of the specifications. The study of iron-carbon alloys has shown the great advantages that can be derived from an adequate heat treatment of the steel.

The most important point in forging is to fix the limits of the temperature within which it is possible to conduct it. The highest of course must be the temperature at which the cohesion of the grains of metal begins to weaken and the grains to separate; this last action is due also in part to the gas evolved from within the mass. The generally admitted hypothesis is that this gas is carbon dioxide formed by the oxygen passing through the metal and combining with the carbon, though it is possible that carbon monoxide and other gases, such as nitrogen and hydrogen are also given off. When a steel is in this state it is said to be burnt, a condition which is chiefly distinguished from the overheated state by the separation of the grains. To this can, perhaps, be added the great thickness of the ferrite network, which is found when the steel cools through the temperature interval, Ar_3 Ar_1. It can be said that the upper limit of temperature for forging the steel for gun construction is between 1,100°-1,000° C. The lower limit must be that of the transformation of the metal, as below this temperature the structure is not changed. This is the natural

and logical limit; but some authors, especially Tschernoff, think that forging at lower temperatures is convenient. But certainly Tschernoff would find it difficult, and even impossible, with the means at his disposal when he wrote his celebrated paper, to forge the large mass required for great guns at temperatures below the transformation point.

Coming now to the practical aspect of forging large ingots for gun construction, it must be emphasized that it is necessary to heat them very carefully and slowly. If the temperature of the furnace, when the ingots are introduced, is rather high, it is better to pre-heat them. Certainly the temperature of the furnace is suddenly lowered by the introduction of cold ingots, which naturally take a great part of the heat lost by the furnace; but this heat, taken up suddenly, causes a sudden dilatation of the outside of the ingot with the natural consequence of cracks, and it may occasion the breaking of the ingot across. This happens especially if the metal is some-

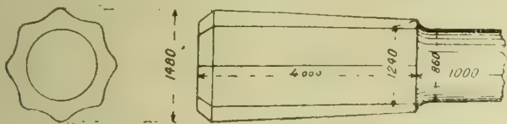


Fig. 3.

what hard. The two reheating furnaces for the great forging press at Trubia are of the Whitworth type. Their doors are worked by hydraulic power. The largest ingots, until recently, forged at Trubia, were 42 tons weight, suitable for the forging of the tubes and other elements of the 24 centimetres and 45 calibres. As an instance of solid forging, that of the A tube for the 24-centimetre gun may be taken. The ingot, on being taken out of the mould, was 16ft. 6in. in total length, of which 13 feet corresponded to the pyramidal part, cast in the metal mould, and the other 3ft. 6in. to the conical part cast in the refractory material attachment. The diameter at the two bases of the tronco-pyramidal part was respectively 4ft. 10in. and 4ft. The mean diameter of the truncated cone part was 2ft. 8in. (see Fig. 3). The ingot free from all cracks, and reduced to a diameter of about 2ft. 8in. by the previous forging, was put in the furnace, where it was heated carefully and very slowly during 30 hours, which is a sufficient time for the whole mass to become well and uniformly heated throughout. The temperature, as already stated, was 1,100° C. approximately, and the forging operation is suspended at 700° C., when the ingot is put into the furnace again. The operation was finished in three heats, and the time taken to complete it after the first heating was 15 hours. The tube weighed 18·5 tons after forging, and its dimensions are given in Fig. 4. For the hollow forged tubes and hoops, 40-ton ingots are also employed. From each ingot two B tubes are forged. The operation of removing the cracks and also of the previous forging are the same as those practised with the ingots for the A tubes. Afterwards the blocks are sent to the large boring machine, supplied by Sir William Armstrong, Whitworth, & Co., where they are bored from both ends at the same time to a diameter of 1ft. right through. When this operation is finished, the ingot is cut into two halves. The reheating is performed in the same furnaces, and conducted with the precautions already described in the case of the A tubes. The duration of the first heating is 30 hours, and the first operation practised is that of enlarging the bore in a Whitworth drawing press. When the operation is finished throughout the length of the tube, the latter has a larger diameter and less thickness than at the beginning of the operation. The tube then goes again to the furnace, and after careful heating the forging is continued, and it is again stretched on mandrils of different diameters. The full operation involves four reheatings, and the total duration is from 13 to 14 hours, the final dimensions of the tube being: total length 17ft. 2in., and outside diameters 2ft. 4in. in a length of about 20in., and of 2ft. 3in. in the rest of the piece. The inside diameter is 14in. The great hoops are forged by means similar to those employed with the B tubes. Sometimes when the ingots from which they are obtained are not very long, the hole for the mandril is punched in the press after being carefully reheated, instead of being bored in the machine. This operation is made in one heat, the hole being driven by a conical steel tool which enlarges and lengthens the hole. When half of the ingot has been treated it is turned and the operation repeated on the second half. It is preferable to bore the ingot, because in this manner the steel of the central part, with a chemical composition distinct from the rest of the ingot due to segregation, is eliminated. Forging after boring must be practised (in preference to forging the solid ingot) when possible, because the action of the press is more energetic in the first than in the second case, the press acting on less thickness of metal. With hoop No. 1 for a 24-centimetre gun, forged hollow, the following notable tensile results were obtained after the full heat treatment. At one end of the hoop, the mean result of three test-bars was 52 tons per square inch tenacity, and 17 per cent. elongation measured in 4in., and at the other end 54 tons tenacity and 17 per cent. elongation, conditions better than those ordinarily specified for nickel gun steel.

Annealing after Forging.—This is an indispensable operation in the manufacture of steel for guns. If it were possible to finish the forging of a piece in one heat only and in such a manner that the whole piece was finished at an even and correct temperature, then, in this case only, the annealing operation could be dispensed with. Some think the operation superfluous, as the piece must be heated to a higher temperature for the hardening process or to a temperature at least equal to that required in the annealing. But forging cannot be conducted in the ideal manner just described, nor is it possible, in the last period, to heat the A tubes for large guns uniformly throughout their length. The lack of uniformity in the finishing temperature requires that the pieces should be annealed before passing to the machine shops, to be prepared for the hardening process. After annealing, the metal will be in the best possible state for the turning and boring operations, and the pieces are less likely to suffer deformation during handling. In being reheated, preparatory to hardening, they retain their shape better, and in taking them out of the furnace for cooling they are less likely to bend, and they undergo less deformation in the process of hardening. The slight deformation in the finishing mechanical operations is also avoided, and exposure to direct sunlight has less effect. Owing to these special circumstances, the Government of the United States specify, in the construction of howitzers, that the shops of the Niles Company, in Hamilton, Ohio, must be always at the same temperature. At Trubia, for the annealing after forging, the same furnaces are used as for the hardening. The operation is conducted very carefully, the temperature in all parts of the furnace, and of the piece, being measured with a Le Chatelier pyrometer. When furnace and piece are at the proper uniform temperature, the gas is shut off and the piece cools slowly in the furnace. Of course the annealing temperature must be above the transformation point. The

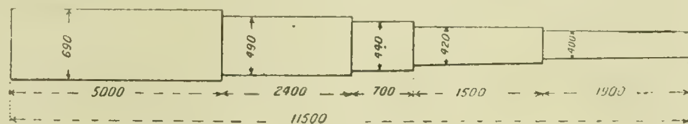


Fig. 4.

elements for field guns are annealed in a special furnace. Taking into consideration their small mass, they are not individually annealed, but eight or ten are put into the furnace at a time. They are heated to 900° very carefully, and after reaching this temperature they are slowly cooled. The author thinks that the advantages obtained by annealing after forging, are more marked in the elements for the field guns.

Hardening and Tempering.

The author has already endeavoured to demonstrate the necessity of subjecting to a certain heat treatment the steel for gun construction. This heat treatment comprises one or more hardenings and temperings as required in order to satisfy the specifications; and the heat treatment must comprise precisely the hardening and tempering. It is also well to insist on calling the second operation tempering and not annealing, because in preparing the pieces for this operation they are heated to a temperature below the transformation point. If they were heated to a temperature above that point and then cooled slowly the structure of metal created by the hardening

process would absolutely disappear. Perfect hardening indicates in the metal a state of unstable equilibrium at ordinary temperature, because this state is that of equilibrium at a temperature above that of the transformation point. Mr. George Ede claimed that the hardening in oil for the elements of guns originated in England at Woolwich Arsenal. The process originated in consideration of the benefits derived from the hardening in oil of hard steel for tools, and in treating the milder steels employed in the manufacture of guns in the same way it was found that the mechanical properties were improved. Tschernoff, in his celebrated paper on the Working of Steel, says that for securing uniformity and fine grain it is necessary, after finishing the forging, to reheat the piece to a temperature above the point *b*, which is that of the transformation in his scale, and then to fix the amorphous texture by rapidly cooling it; this amorphous texture will be more surely obtained, the rapidity of cooling being the same, the less the point *b* in the reheating be exceeded.

Fig. 5.

Tschernoff and Woolwich Arsenal coincide in the treatment after forging to be given to the elements for gun steel, and this has led perhaps to the process being adopted by some manufacturing firms in other countries. At the Krupp works the elements for guns are said not to be hardened and tempered. The author has explained in another part of this paper the reasons why the metal must be subjected to heat treatment, and it is not necessary to repeat them here. In England and in the United States oil is exclusively employed as a refrigerant liquid; in France and Spain (Trubia Arsenal) water is used. Between hardening in oil and hardening in water, the temperature (always above that of transformation) being equal, the difference is very considerable, owing solely to the rapidity of cooling. In accordance with the remarkable work of Le Chatelier, which forms a very interesting paper in the "Bulletin de la Société d'Encouragement pour l'Industrie Nationale," No. 9, Vol. CVI., there is a well-marked difference in the rapidity of cooling a piece in water or in oil. This was well known from the time hardening was first practised, but Le Chatelier measured mathematically the rate of cooling. He operated with very small pieces, and took into consideration the extreme interval of temperature, which must be rapidly passed for realising the hardening. Knowing that the recalescence phenomenon is never produced on cooling to a temperature superior to 700° C., and that the tempering is not influenced by temperature down to 700° C., he only took into consideration in his experiments the time spent in passing from 700° C. to 600° C., which time, all the remaining conditions being equal, gives a very accurate notion, almost mathematically exact, of the rapidity of cooling, and therefore of the energy of the hardening. The central part of the sample, hardened in pure water, employed five seconds in passing from the temperature of 700° C. to that of 600° C. In the oil hardening for passing the same interval 43 seconds were required, that is, the time was seven times longer than with the pure water. It must be said that in this experiment of Le Chatelier with oil, the rapidity of cooling was much less in the interval of 190° C. to 100° C., in which interval 30 seconds were spent. It is natural that this happens with all the refrigerant liquids, but in oil it much more marked, and the explanation is, according to Le Chatelier, that during the operation the oil is decomposed and the gaseous bubbles cause a circulation of the liquid, which must cease at the end of the cooling. From these experiments, confirming by a scientific method all that was known, it is possible to state what will be the difference of hardening which two elements heated to the same temperature and cooled in two liquids, both also at the same temperature, should take. If the elements hardened in both liquids were intended for large guns, and if they should possess great thickness, there would be sufficient reasons for thinking that none of the pieces would possess, at the ordinary temperature, the structure which it possessed at the beginning of cooling. But surely the piece hardened in water should be the nearest to this structure. Benedicks, in a paper recently read before this Institute, has made experiments on hardening in a manner very similar to that of Le Chatelier. He says that the most important factor in the rapidity of cooling is neither the conductivity nor the specific heat, but the latent heat of vaporisation of the liquid. The specific heat has a secondary influence, and it is possible to dispense with the heat conductivity. The necessary conditions for obtaining from a given bath an efficacious hardening are as follow:—

(1) A high latent heat at vaporisation.

(2) A low temperature, in order that the vapour bubbles, generated in the surface of the metal, might be easily condensed in the ambient liquid. Whatever may be the predominant factor in the rapidity of cooling, the hardening in water will always be more energetic than the hardening in oil. Therefore, there is no doubt that the hardening in water will require a subsequent tempering, more energetic at a higher temperature than would have been necessary if the hardening had taken place in oil, in order to enable the metal to stand the tensile and shock tests specified. Really the hardening temperature must be higher than that of the transformation point, so that in submerging the piece in the refrigerant liquid the cooling might begin when the steel is yet at a higher temperature than that of the transformation. At the Trubia Arsenal in the hardening of the elements for gun construction, water, as already mentioned is employed as refrigerant liquid. The hardening plant is shown in Fig. 5. The reheating furnaces are vertical, and are heated by gas from three Dowson producers. The large furnace is capable of taking pieces 40ft. in length, and has four inlets for the gas, regularly spaced. It is built upon the ground floor, and, as is natural in these conditions, the tubes are manipulated through a lateral port, hydraulically. The second furnace is of greater diameter than the

Fig. 6.

first, and its length is 26ft. It is intended for the reheating of the B tubes and hoops, also for the tubes of the medium guns up to 6in. calibre. The water tank is situated between the two furnaces, and has the dimensions stated in the drawing. The water, at the time of the cooling, has a temperature of 20° C. A 35-ton overhead travelling crane is driven by a rope worked by a steam engine, and serves the whole of the

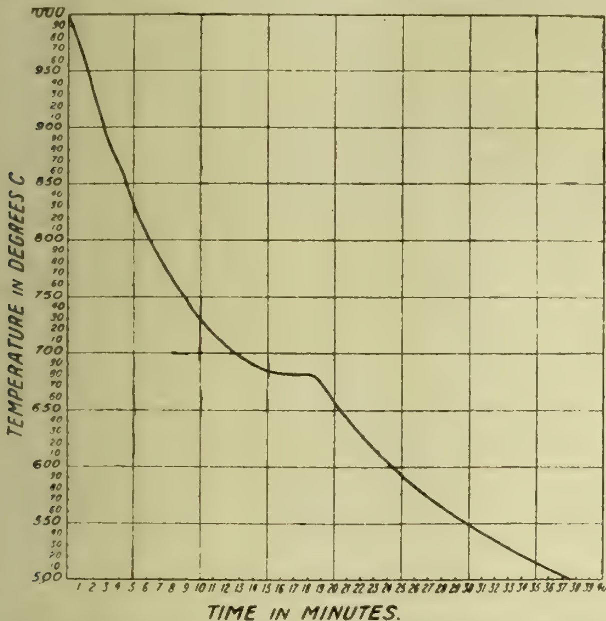


FIG. 7.—COOLING CURVE FOR ORDINARY GUN STEEL (CARBON STEEL).

hardening shop. When this plant was installed 12 years ago the intention was to use oil as a refrigerant liquid, as was the practice at Trubia with all the guns manufactured before that date, which did not exceed 6in. calibre. In accordance with this idea, four tanks capable of containing more than 100 cubic metres of oil were conveniently installed at the top of the building, under the roof, and another four tanks of the same cubic capacity were installed at the outside of the shop, and on a level lower than the ground floor. The hardening tank is in communication with the higher and lower tanks by means of a system of pipes which are worked by the necessary pass valves. A steam pump can elevate the liquid, when it is cooled, from the lower refrigerant tanks to the higher, and during the hardening it is possible to maintain a constant current of oil in such a manner that that of the hardening tank should not take a temperature so high that the piece instead of being hardened is annealed.

As is seen from the drawing, the capacity of the shop is limited to the hardening of elements for 10in. guns and 45 calibres in length.

The measuring of the temperatures is done by the aid of the Le Chatelier thermo-electric pyrometer, registering the temperature of the tube or hardened piece at different points in order to distribute the heat in such a manner that the temperature may be uniform. Undoubtedly the best method is that followed at Woolwich Arsenal, with the long tubes for the 12in. guns of 45 and 50 calibres, where four or five Le Chatelier pyrometers are installed, with registering apparatus, and regularly distributed all along the tube; that is both convenient and necessary when operating with tubes for guns of 51ft. in length, or perhaps more, with the excess length left at both ends for the test pieces. It is really very difficult to heat uniformly the long pieces of variable thicknesses, and therefore to harden them. The difference of operating as physical experimenters do in their laboratories with samples of some grammes weight, and of dealing with 15, 20, 25, and 30 ton pieces, as is the daily practice of the manufacturers of gun steel, is enormous. By carrying out the hardening in the ordinary way, the cooling of the metal begins at the inside and outside surfaces at the same time. If the cooling is more rapid at the inside the interior layers near this surface will be compressed and the exterior layers will be in tension. The reverse will happen if the cooling is more rapid at the exterior than at the interior surface. The best condition for the resistance of guns is that the first case should occur, and then not only will the improvement in the structure derived from the hardening be obtained, but the steel will be in ideal condition for withstanding the pressure of the powder gases. Upon such considerations was established the St. Etienne process, which consisted in cooling the tubes on the inside only. But this process had the great disadvantage that if certainty was attained that the piece was in the best conditions for the resistance of the pressure of the gases, the uniformity of the hardening, and therefore of the structure due to uniform rate of cooling throughout the whole piece, was lost.

If tensions or compressions have been produced the layers of metal must be distended or compressed. Knowing the tensile characteristics of the metal, it is very easy to measure the intensity of the tensions or compressions, as they are of a purely elastic character, and it is possible to plot a diagram representing the variation of tensile strength in terms of the thickness of the piece. In the ordinary practice of conducting the hardening operation in the tubes intended for gun construction the result generally is that the outside surface is compressed, that is to say, the contrary of what must be most convenient for the strength of the gun. With hardening in water, and dealing with carbon steel of 0·5 per cent., the tempering operation is absolutely necessary. Even when the piece has been heated and hardened with absolute uniformity, and the elastic tension caused by the hardening should be the most suitable for the strength of the gun, the tempering of the piece would be absolutely necessary, because the hardness due to the hardening would make it very difficult, if not impossible, to machine the piece in ordinary conditions of work, and the tensile, bending, and dynamical properties would not be in accordance with the specifications. In hardening in oil, in nearly all cases, tempering at a very low temperature, in order to cause the disappearance of the light stresses originated, is sufficient, but in water hardening, and with metals of 0·5 per cent. of carbon, the tempering temperature will be near that of the transformation point.

Ordinarily that necessary for obtaining the best tensile properties is about 600° C. It is clear that if these properties, after the heat treatment, are deficient from those specified, or lower than those required, it would be necessary to submit the piece to fresh heat treatment, raising the temperature of hardening and keeping constant that of tempering, or the same result can be obtained by giving the piece a new hardening at the same temperature and lowering that of tempering. If, on the contrary, the tenacity were higher and the ductility

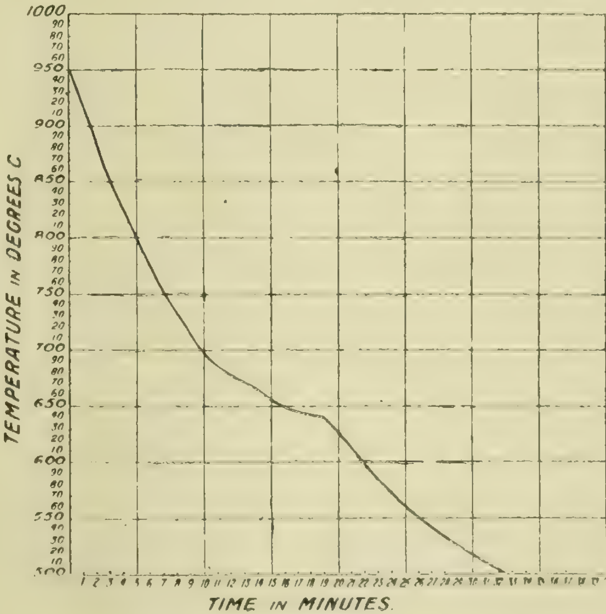


FIG. 8. COOLING CURVE FOR NICKEL STEEL.

less than required, the results can be rectified by giving the piece a new tempering at a higher temperature.

Cooling Curves.—Even though the cooling curves of different types of steel are well known, the author believes it useful to give in this paper those of both types of artillery steel, carbon, and nickel steels (Figs. 7 and 8), the latter being employed in the manufacture of field and medium guns. Owing to certain difficulties at the Trubia Laboratory, it has not been possible to obtain the curves of both steels from the liquid state. The range of cooling is therefore from 1,000° C.

to 500° C. for ordinary steel, and from 950° C. to 500° C. for nickel steel. Within this range are found the transformation points, so important for the proper treatment of the metal in all the heat treatment operations. Observing first the cooling curve of the ordinary steel, it is seen that the cooling curve is generally in accordance with the well-known Newton's law, and that the curve has only a well-marked point Ar_1 at 684° C. At this temperature the curve is converted into a horizontal line for a length of 20 mm., indicating 200 seconds or 3 minutes 20 seconds. The temperature is therefore constant during this period, indicating complete equilibrium of the two component systems, iron-carbon. This is the range during which the solid solution or martensite, stable at a temperature below 684° C., is transformed into ferrite and pearlite constituents, with less than 0·89 per cent. carbon, stable at a temperature below 684° C. for this particular steel. Certainly it would not have been difficult to calculate the heat of transformation of this steel, taking into account the weight of the sample and its specific heat. From the transformation range the rate of cooling diminishes, in accordance also with Newton's law. Nickel steel shows also a small point of transformation at 656° C., the horizontal not being as well marked as in the curve of the ordinary carbon steel. All that has been said on behalf of this is applicable to ternary nickel steel.

RATEAU-SMOOT MIXED FLOW TURBINE.

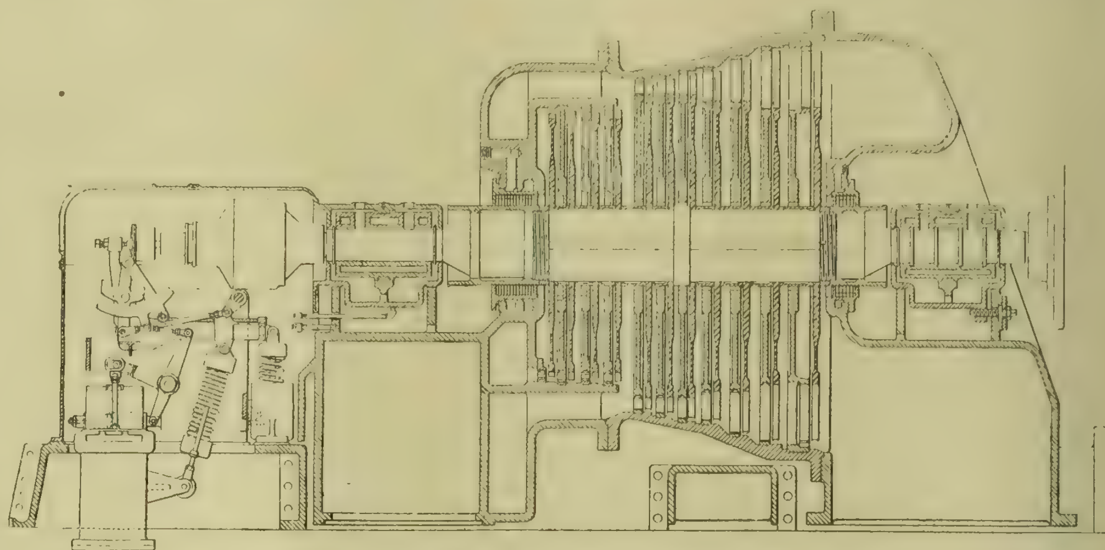
THE Illinois Steel Company has put in operation recently a low-pressure turbine installation at the South Works, South Chicago. It utilises the exhaust steam of several reversing engines. The exhaust steam is directed into five steam regenerators furnished by the Rateau Steam Regenerator Company, New York. This equipment is designed so that the intermittent flux of exhaust steam may be transformed into a steady flow, taking care of full load on the steam turbines not only during the mill cycle, but also when the mill cycle is interrupted for periods not exceeding 2 minutes.

The steam turbines are mixed flow machines of the Rateau-Smoot type. They were designed by C. H. Smoot, of the Rateau-Smoot Company, and manufactured by the Southwark Foundry and Machine Company. We are indebted to the "Iron Age" for the accompanying particulars of the turbine, which has an entirely independent high-pressure section. High-pressure steam passes through the high-pressure wheels and after being expanded enters the low-pressure section. In other words, the turbine when working on live steam is a complete high-pressure machine. Around the high-pressure section of the turbine the low-pressure steam is admitted direct to the low-pressure wheels. By means of this arrangement the highest possible economy obtainable, it is claimed, is attained when working on either high or low pressure steam.

The governor is designed so that the pressure of the low-pressure steam may control the selection of the source of steam and so that no live steam is admitted to the turbine before the low-pressure steam has become deficient; in other words, when the pressure in the low-pressure source has reached atmospheric pressure in this instance. This occurs when the steam regenerators have been delivering steam during a shut-down of the mill engines for a period of more than 2 minutes and during this period the turbine has been carrying full load. The turbine is rated at 3,000 kw. when using low-pressure steam exclusively and 4,000 kw. continuous load when using high-pressure steam. A second turbine is under construction for the works.

The bearings have ring-oiled lubrication with water cooling in the bushings, and this is said to be the largest turbine in the world having this form of lubrication and of bearing cooling, which is independent of the continuity of operation of oil pumps or other auxiliary devices. The stuffing-boxes are built up of a number of consecutive rings of carbon blocks separated by diaphragms and provided with springs to hold the carbons in contact with the shaft.

The governor is direct acting. The fly balls and spring against which they actuate are mounted within a steel shell, which is fixed directly on the high pressure end of the turbine shaft. The motion of the fly balls is transmitted by means of links directly to the high and low pressure throttle valves. The governor is powerful to enable it to have a very active control over the displacement of throttle valves, and has been found to give a high degree of regulation at the Illinois Steel plant. When first put into service the turbine regulation was adjusted for 3 per cent., changing from no load to full load. When placed in parallel with other machines it was observed that the turbine took all of the load when it increased and dropped most of its load when the load decreased, owing to the fact that the other machines with which it was in parallel were not so closely regulated, and it was found necessary to readjust the governor so as to give a 6 per cent. difference between no load and full load speed in order that the unit might carry at all times its proper share of the load on the entire system. The governing mechanism is arranged so that the action of the fly balls is to hold open the valves, and in consequence the breakage or disconnection of any of the links between fly balls and valves works to close the valves by their own weight, the high pressure valve, in addition, being assisted by a closing spring.



RATEAU-SMOOT TURBINE USING BOTH HIGH-PRESSURE AND LOW-PRESSURE STEAM.

The mixed flow feature of the governor includes a piston actuated by the low-pressure steam, which rises and falls with the pressure in the low-pressure steam main. When the low-pressure steam has a high pressure (in this case some 20lbs.), the piston allows the fly-ball governor to actuate the low-pressure valve for its full travel while holding the high-pressure valve in a closed position at all times. As the quantity of low-pressure steam decreases, the piston which it actuates descends, giving a greatly increased opening to the high-pressure valve until it reaches its lower limit, under which conditions the low-pressure valve is in a closed position and the high-pressure valve is actuated by the fly balls for its maximum displacement. An intermittent position of the control piston gives a simultaneous opening to both high and low pressure valves.

Expert Education in Petroleum Mining.—In view of the development of the petroleum industry, the University of Birmingham, which already has provided special courses in petroleum mining, has prepared a syllabus to cover the course for the degree of B.Sc. (in Petroleum Mining) and the Diploma in Petroleum Mining. The course comprises an education in the principles and practice of mining, boring, surveying, and bore-hole surveying, petroleum mining law, and the transport, storage, and refining of petroleum.

CONTINENTAL DESIGNS OF BURNERS FOR WELDING AND CUTTING METALS.

A review of some German designs of burners for welding and cutting metals appeared in a recent issue of "Elektro-technischer Anzeiger," and we are indebted for the following translation to the Journal of the American Society of Mechanical Engineers.

The Jurgens gas blower (Fig. 1) is a combination of a Bunsen burner and a blow-pipe. The blower rotates on the support *f*, and is provided with air and gas ducts *l* and *g*, the air duct *l* connecting with the gas duct when the cock *h*, with its angle bore, is placed in a suitable position. The gas duct *g* is further divided into two separate ducts k^1 and k^2 leading to the respective plugs of the cock *h*. The gas flows through these ducts into the burner pipe *b* from which either a Bunsen flame or a blow-pipe flame may be produced. In the first case the air admission sleeve is placed so that its holes are just over the holes in the burner pipe, giving free admission to the air. The rotation of the sleeve is accompanied, by means of the pin *m*, by a displacement of the slide valve *sch* opening to the gas a passage into the burner pipe through the little holes p^1 and p^2. If the burner is used as a blow-pipe the sleeve *z* is brought to where it covers the holes in the burner pipes, whereby the slide valve *sch* is placed so that the large openings d^1 and d^2 are brought over the ducts k^1 and k^2, and compressed air let on.

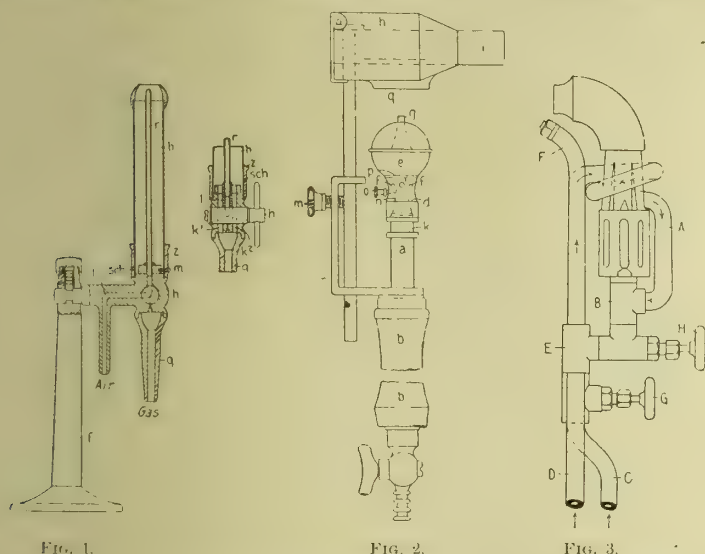


Fig. 1. Fig. 2. Fig. 3.

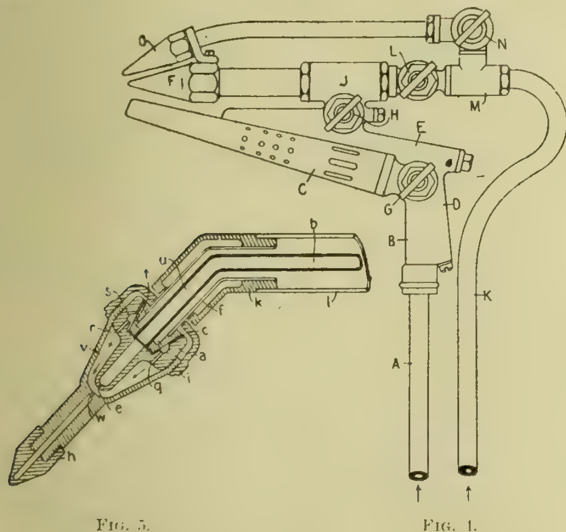


Fig. 5. Fig. 4.

Fig. 2 shows the soldering acetylene-heated iron of Tr. Baumann, in Winterlingen, Germany. The gas pipe *a* is provided with a cock and ends in a nozzle *d* enclosed in the shaft of a spherical burner *e*, this shaft being provided with air admission openings *f*. The nozzle *d* ends in a conical extension *g*, the purpose of which is to produce a narrow flame directed on the iron *i* surrounded by the jacket *h*, with its openings *q*. There is also a spring *n*, which can be regulated by the screw *o* so that its tip *p* closes more or less the opening of the nozzle *d*, and thus makes the flame strong or weak as desired. A wire gauze screen is provided at *k* to prevent backfiring.

In the production of burners using liquid fuel, more economical thermally and less dangerous than acetylene burners, two improvements are credited to Edward Grube, in Alt-Rahlstedt, Germany. The liquid fuel must of course be evaporated before it can mix with the air. The first is shown in Fig. 3. A burner with a single superheater coil A, from which oil vapour is conducted to the distributing member B, and is supplied simultaneously to the injectors E and nozzle. The oil vapour formed in the superheater coil A produces a narrow flame at the exit from the nozzle, as in an ordinary blow-pipe, but serves also to feed the welding burner F. For this purpose part of the oil vapour is led aside into the injector E, and mixes there with the oxygen. To start the burner the superheater coil A, with all valves closed, has to be heated by some outside source of heat. To use the burner for welding purposes the cock H has to be opened, and oxygen admitted to the injector E through the pipe D.

In the second burner of the same concern (Fig. 4), the oil which is lead to the burner through the pipe A under pressure, enters into the carburetter B of the blow-pipe E as well as through a side duct D, into the carburetter E of the welding pipe F. The valves G and H regulate the supply of the oil vapour. The carburetter B is heated by the heat conducted through the metal from the pipe C of the blow-pipe, while the carburetter E is directly surrounded by the flame of the blow-pipe. From E the oil vapour passes into the injector J, and mixes there with the oxygen coming through the pipe K, the flow of the oxygen being regulated by the valve L. A branch pipe M, with cock N, permits also the regulation of the supply of oxygen flowing under high pressure to the torch for cutting metals O.

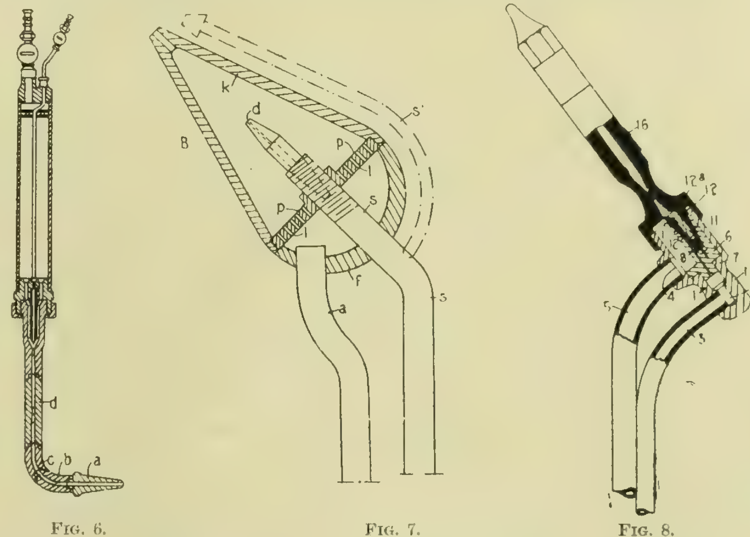


Fig. 6. Fig. 7. Fig. 8.

To obviate the necessity of having several burners of various sizes for different kinds of work, J. Ammon, in Schoneberg (near Berlin), designed a burner (Fig. 5) for welding which may be fitted with different nozzles for different kinds of work. The part *g* is a nozzle body provided with properly dimensioned ducts for oxygen and fuel gas, with the nozzle and outer tube in permanent connection. The nozzle body *e* is slipped over the hollow conical nipple C, connected with the oxygen pipe B and combustible gas chamber L, the two being connected when necessary by the cap screw I. The oxygen flows through the pipe B into the duct W, and out through the burner nozzle H. The fuel gas is drawn by the suction, produced by the flow of oxygen, through the duct T, into the passage S, and thence through the duct R into the combustion chamber V. Another burner on the same principle, but somewhat different in constructive details, has been designed by W. Widmann, in Stuttgart, Germany.

The vapour nozzle of the welding burner of the Rheinische Gesellschaft for autogene Metallbearbeitung m.b.H., in Cologne (Fig. 6), consists of several exchangeable parts. The nozzle proper, consisting of three parts, *a*, *b*, *c*, is screwed

to the mixing tube *d*, these three parts being provided with similar threads, so that they may be set at any desired angle to the axis of the mixing tube.

The burner of M. Imhoff, of Berlin (Fig. 7), which may be used both for welding and cutting metals, is constructed so that the oxygen cannot get into the gas pipes. The pear-shaped burner B consists of a semi-spherical base F and conical vapour nozzle K, divided by the plate P having a large number of small holes L arranged in concentric circles. Acetylene is brought through A, oxygen through the pipe S passing through the base and plate P, and provided with the nozzle D. The mixture of oxygen and gas flows out through the nozzle *k*. When the burner is used for cutting metals, an additional stream of oxygen is supplied through the branch piping S[1]. The peculiar shape of the burner permits of cutting a number of holes in the plate P such as to allow always a sufficient supply of gas to flow through, with no danger of backfiring. The conical extension K is said to favour the mixing of the two gases.

Instead of making provisions for exchanging nozzles, the admission of oxygen may be regulated, as is done in the burner of the Apparate-Bau Anstalt Schmalkalden G.m.b.H., in Schmalkalden, Germany (Fig. 8). The oxygen pipe 3 opens into the chamber 2, while the acetylene pipe 5 is led to the side opening 4. The headpiece 6 is screwed into the casing 1, and is provided with a central duct, with the front part of 6 eccentrically located, and fitted with cone 11 having in its turn longitudinal grooves 12 opening into ducts 12ª. These ducts are cut in special nozzle-shaped pins connected with

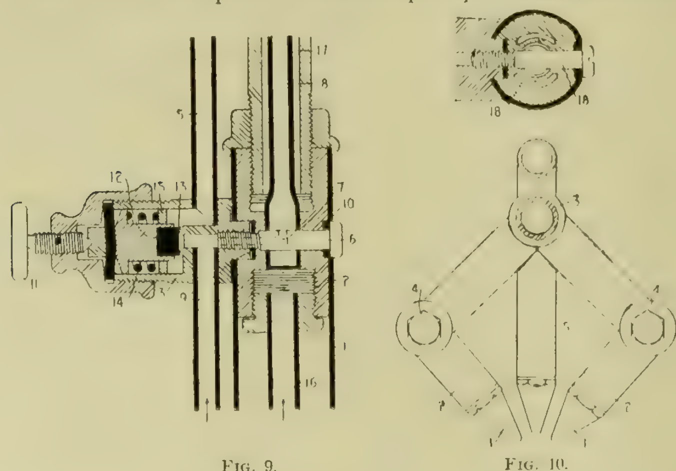


FIG. 9. FIG. 10.

cone 11, are of different diameters, and, like the grooves 12, are not limited as to number. Since the path of the oxygen lies through 12ª enclosed in the cone or pins connected with it, the regulation of the oxygen is not affected by regrinding.

What is claimed to be a new arrangement for distributing the oxygen in burners with a single oxygen piping is embodied in the burner shown in Fig. 9, constructed by J. Knappich, in Augsburg, Germany. The oxygen regulating valve 3, with its admission and discharge piping 4 and 5, is fastened by the screw 6 to the body 2 enclosed in a tube protector 1. The screw passes through the duct 8 for the admission of oxygen for the preheater flame, this duct being closed below the screw, and the screw being provided with a bore 7 connecting the oxygen supply pipes 4 and 8. The inside diameter of 8 is so large that there is always a sufficient area for the passage of the gas, independent of the position of the screw 6. The discs 9 and 10 act as packing. By means of the screw 11 the valve 3 can be closed or opened, according as the valve cone 12 is pressed against its seat 13, or lifted from it by the spring 14 having as purchase the disc 15. The fuel gas pipes 16 and 17 are tightly fastened to the body 2, the two pipes being connected by the ducts 18. When valve 3 is open, the oxygen brought by pipe 4 flows into 8 as well as into 5. When the valve is closed, the admission of oxygen into the oxidation pipe 5 is stopped, but the gas continues to flow through 7 into the pipe 8.

In the torch for cutting metals of R. Moritz, of Wasquehal, France (Fig. 10), the nozzles of the fuel gas supply pipes are on pin joints, thus permitting the regulation of the heated space opposite the oxidation nozzle. Oxygen is supplied by the pipe 5, and fuel gas by the nozzles 1.

TAPS AND SCREWS.

AT the meeting of the American Society of Mechanical Engineers held in New York, on March 12th, a paper by F. O. Wells, of the Wells Brothers Company, Greenfield, Mass., was presented by H. E. Harris, testing engineer for the company, on "Taps and Screws." The average user of machine screws and bolts hears very little about the finely drawn theories in regard to angles and other details and their practical application to tap and die making. The ability to buy or make screws and bolts which can be depended upon to fit the tapped holes in the product under manufacture is, however, a matter which demands attention. Differences in the dimensions of the screws and the tapped holes must be made in order to allow for unavoidable imperfections in manufacture and wear on the taps and sufficient freedom of fit, but this should be confined to such small limits that the smallest permissible

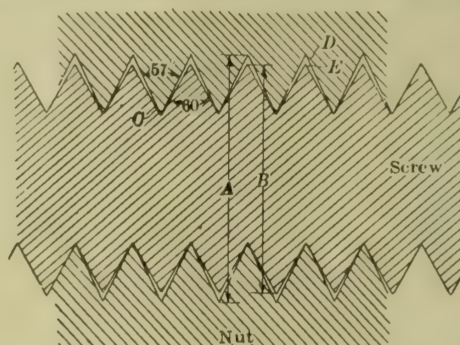


FIG. 1.—EFFECT OF FITTING NUTS AND SCREWS OF DIFFERENT ANGLES TOGETHER.

diameter for the taps will be slightly larger than the largest permissible diameter for the screws. If these limits are too large, a screw which happens to be used in a hole tapped by a maximum-sized tap may be too loose. The limits must be closely guarded; but at the same time they must not be so small as to prevent an interchangeable assembling, and must also allow for a reasonable amount of wear on the tap.

The two factors most vital in this connection are the size and the lead. It is very important to understand how the size is to be measured. The fit of any screw should be on the sides of the angle of the thread, as the outside and root diameters have comparatively little to do with the actual fit; for, unless the angle and the lead of the threads are the same in both screw and tapped hole, and the diameters measured across the angles of the threads are relatively right a proper

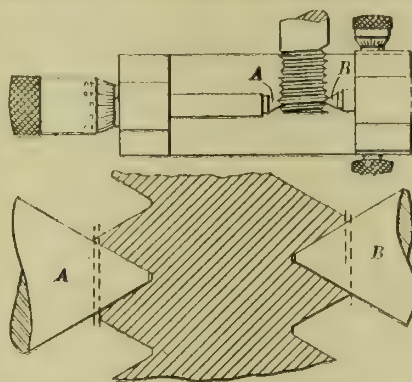


FIG. 2.—MICROMETER FOR MEASURING DIAMETER OF SCREWS ACROSS THE ANGLE.

fit cannot be obtained, no matter how close to size the outside and root diameters are held. Fig. 1 shows one effect of fitting together nuts and screws of different angles. In this case the screw is shown with a more obtuse angle than the nut, and the bearing between them, if one could be obtained this way, would be on the sharp, fragile apexes of the teeth.

The necessity of measuring the angle accurately has led to the adoption of the term pitch diameter for screw threads, as well as for gears, and those who have gone carefully into the study of screw threads are using exclusively this method of measuring. Fig. 2 shows a micrometer which measures these important diameters across the angle. The great merit of this particular tool is that it is not rendered inaccurate by the helix angle of the thread; that it will measure the finest lead

thread as well as the coarsest within its range, and that it has the greatest range that has been developed.

Fig. 3 shows how variations in the lead affect the pitch of a screw. The angle in this case has been assumed to be correct, but the nut has been tapped with a tap having long or stretched lead, with the result that a bearing can be had only in two places at the most, as indicated by A D and B C. This is not by any means an exaggerated condition and explains the reason why a nut, tapped with a large diameter tap, will often start freely on a screw, turn a few turns, gradually becoming less free, and then bind. It has then found its A D and B C and cannot move further, because the position of the bearing on opposite sides of the thread acts as a wedge.

While it is possible that on small work and with soft metals

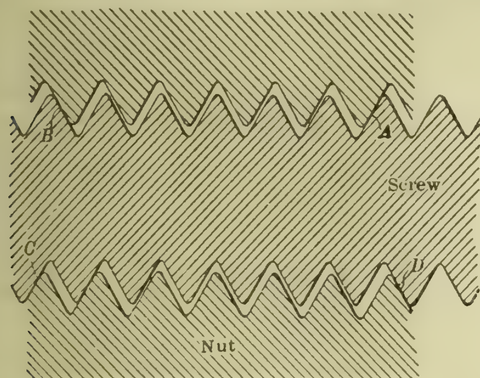


Fig. 3.—Effect of Variation in Lead upon Pitch of Screw.

screws might be put together in this way, it is very evident that it would not be a good job and would very soon prove unsatisfactory. It would also tend to place all the strain on one tooth at a time, making it possible, under a sufficient longitudinal strain, to strip one tooth after another with a shearing action, at a small percentage of the power that would be required to strip them all simultaneously when the lead is correct.

As stated, the user generally desires only to have his screws and bolts fit satisfactorily. Those who do a large amount of assembling, where thousands of screws of various sizes are used, know the difficulty of this proposition. They are acquainted with the variation to be found in machine screws, as well as in the tapped holes, and with the delay which this makes in assembling, as well as with the difficulty of supplying duplicate parts. For this reason, many are using point limit gauges especially made to measure the screw diameters across the angles, and so ensure the uniformity, within working limits, of the screws to be used.

As to the lead of taps, there is little doubt that most makers use a somewhat similar method to secure uniformity of product. It must be remembered, however, that as all steel expands and contracts with heat and cold, taps change their lead to some extent in the hardening process. If, in addition to this, they are warped on the threaded end, the lead, the angle, and diameter of the tapped hole will be affected, as can be seen in Fig. 4.

To what has been said of the effect on taps of errors in lead, angle, angle diameter, and warping, must be added the effect of usage in reducing the size of the tap by wear, as well as the commercial variations of lead, angle, and diameter in the screws or bolts, and it will readily be seen that under the best possible conditions there will be a multiplicity of minute errors that will have to be taken care of by the allowance between the minimum limit of the tap and the maximum limit of the screw. There will also have to be a maximum limit set on the tap and a minimum limit set for the screw, to provide for manufacturing allowances and to prevent too much looseness in the fit of the thread.

There is great diversity of opinion at the present time among tap and die makers, and screw makers in general, as to what these allowances should be, and what constitute the correct limits for taps and screws, with the result that a buyer or manufacturer has trouble in securing taps to suit his screws, or screws to fit his tapped holes, and is working under a serious handicap in his efforts towards proper fits and interchangeable work.

The Committee of the Society on the Standard Proportions of Machine Screws gave in its report of 1907 a list of standard machine screw sizes, with diagrams and tables of standard proportions, limits for screws and taps, sizes of references, gauges, &c., which received the endorsement of, and has been of unlimited value to, the industrial community at large. The question of limits for the larger size screw threads was, however, left unsettled, and this question, from its far-reaching nature, is too large a matter to be settled by either the manufacturer or the user.

It is often found, in cases when one would least expect it, that a manufacturer is actually punching or drilling holes for tapping of a smaller diameter than the root diameter of the thread, so that the end of the tap must act as a reamer before the thread can be cut. In this case the tap becomes a taper reamer with unrelieved chip breakers, and reams a taper entrance to the hole. Oftentimes it will fail to "catch the thread" at all, and will therefore ream clear through or to the bottom without threading. Or, if the thread does happen to catch after reaming part way through, a short, weak thread is the result.

This requires considerable power, often beyond the breaking strain, and explains why taps sometimes refuse to cut a thread at all, and also why taps sometimes break almost as soon as they begin to cut. When it is remembered that, generally speaking, more than 80 per cent of the standard thread depth is never necessary in manufacturing, even for shallow holes, and in many cases not more than 50 per cent., the folly of having holes too small can be seen, and, in most cases, even of attempting to secure a full thread.

Tap drill sizes for machine screws in particular should be varied according to the material to be tapped, and the depth of the tapping. Roughly stated, for holes that have the screws enter more than 1½ times the diameter, 50 per cent. or half-thread is usually sufficient, as the head will break off, or the screw will stretch or break before the thread will strip.

Soft, tough material, such as copper, Norway iron, drawn aluminium, &c., should have a larger hole for the tap than the harder and more crystalline materials, such as cast metals. This is because, if they are drilled smaller, the tops of the threads are liable to be torn off, which decreases the effective depth of the thread in the tap hole, and results in a poorer thread than if the hole had been originally drilled a little larger. On the other hand, in these more tenacious ductile materials, if the hole was originally a little large, the tap, especially after the keen edge has become slightly dulled by use, will reduce the size of the hole by spinning or drawing the metal at the tops of the threads, thereby increasing the effective depth of the thread.

It should also be remembered that it is impracticable to tap a hole with the basic root diameter size, unless the much slower processes, with serial taps, or long step taps, are used, so as to divide the tapping operation into a series of successive steps, each removing a small amount of metal. The size of the hole also affects very materially the power required for tapping, and the tap breakage. This is particularly important in machine tapping, which is the main thing to be considered in manufacturing. The power is also affected by the kind of lubricant used, by the condition of the tap, whether sharp or dull, by the shape of the cutting edges and their effect on the

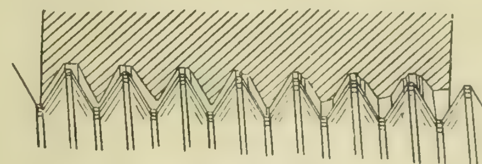


Fig. 4.—Nut Tapped with Tap Warped in Hardening.

shape and action of the chip, and also by the spaces allowed for chip clearance.

As almost all machine tapping is in through holes, and the uses of the bottoming tap are extremely few, experiments were made on the effects of sharpening or grinding the taps back from the end for a varying number of threads, so as to ascertain the effect of dividing the work among more or less cutting teeth. It was found by repeated tests and careful record, that it requires approximately 25 per cent. more power to drive a tap which has been ground back but four threads, which, in a 4-flute tap, divides the cutting among 16 teeth, than for one which has been ground back six threads and having 24 cutting teeth. The 24 cutting teeth also gave much smoother threads,

and cut more closely to size. This shows that for general use, a tap ground back six threads works better and will last longer than one ground back only four.

TABLE I.—*Variations in the Action of Taps on Repetition Tests in Different Materials.*

Taps used ½-13 U. S. S. Root diameter of test pieces 0·420in. Depth of Tapped hole ½in.

Materials used	Test Nos. of Taps. 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Hexagon drawn brass	60 65	62 60	62 65	60 60	65 65	70 80	60 60	90 95	60 62	60 60	60 60	60 62	60 65	65 65
Crucible tool steel ...	220 225	242 265	250 268	230 250	240 230	280 260	250 235	375 380	210 205	270 280	260 275	270 260	260 260	258 270
Cold punched hexagon steel nuts ...	148 130	158 130	168 17[illegible]	170 190	155 160	150 180	150 132	340 360	165 140	195 160	165 225	175 200	148 180	180 180
Hexagon screw stock	140 160	150 170	165 185	188 165	178 210	180 268	155 170	250 430	140 155	240 190	235 200	168 160	225 205	230 205
Drawn hexagon phosphor bronze ...	210 190	175 200	250 300	200 250	230 2[illegible]0	240 250	170 182	338 320	160 190	200 330	220 210	222 245	265 205	210 210

The above values represent the power required in inch-pounds to drive the taps through the test pieces as measured on testing machine.

The effect of different materials upon the power required for tapping is shown in Table I., which gives a chart of the results found on 14 different taps tested on test pieces of five different materials. The maximum and minimum power required by each tap when tapping consecutive test pieces is given in inch-pounds. It will be seen that drawn brass required, on an average, 65in.-lbs. and is very uniform, and that while crucible steel is also a uniform cutting material, it required an average of 261in.-lbs. or four times as much; cold punched hexagon steel nuts required an average of 190in.-lbs., and hexagon screw stock, tapped endwise, 197in.-lbs. Phosphor bronze shows the biggest power variation for the same tap, or throughout the test. It required an average of 228in.-lbs. Taps Nos. 6 and 8 had a slightly poorer form of flute than the rest, and did not cut as smoothly nor as easily, as may be seen by referring to the power readings in the table.

Table II. shows the effect of varying the root diameters and using different lubricants. In this table, which is the final result of a long series of tests, the breaking strain is taken for comparative purposes as a 100 per cent. strain (the power required to break a properly-made ½-13 U. S. S. plug tap is approximately 1,000 in.-lbs.), and the lesser strains required for tapping holes under different conditions are given as percentages of this. The test pieces used were common hexagon cold punched nuts accurately reamed to the respective drill sizes, and the taps used were regular stock ½-13 U. S. S. taps.

The points which this series of tests seem to emphasize particularly are as follows: (*a*) That the lubricants used, up to a certain point, have the same effect on the cutting power required as more or less metal to remove should have. For instance, to tap a ½in. nut with a 0·425in. tap hole, using machine instead of sperm oil, would have practically the same effect on the power required as reducing the diameter of the tap hole 25 per cent. of the double depth of the thread. Referring to Table II., it will be seen that the power is approximately double in both cases, from 16·5 per cent. to 34·2 per cent. on changing from sperm oil to machine oil, and from 16·5 per cent. in the sperm oil column to 35·5 per cent. changing from a 0·425in. to a 0·400in. tap drill hole. (*b*) That animal lard oil, sperm oil, and the graphite and tallow mixture are the best lubricants of those tested. (*c*) That a good cutting compound is better than some mineral lard oils for the purpose of tapping. (*d*) That machine oil is a detriment instead of a help; that taps will cut better dry than with it. (*e*) That the number of breakages can be greatly reduced by the use of a proper lubricant, and that taps should never be used dry in steel. (*f*) That the diameter of the tap drill hole should not be any smaller than is absolutely needed to give the necessary strength, and that if this requires a full depth of thread on any particular size, it would be advisable, from a tapping standpoint, to gain strength by using a larger size of thread in combination with an over-size tap hole. (*g*) If for any reason it is desirable to produce a thread having the full depth, in order to prevent breakage of taps and the tearing of the tops of the threads (which ultimately increases the size of the tap hole), serial taps should be used with the best lubricant obtainable. (*h*) That every decrease of 0·001in. in the diameter of the tap hole materially increases the power required to tap it, and also increases the percentage of broken taps; and that as the tap hole gets smaller, the power required increases and the breakages occur in increasing ratio.

TABLE II.—*Effects of Various Lubricants and Different Tap Drill Diameters on the Cutting Action and Breaking of Taps.*

Lubricant.	Animal Lard Oil, per Cent.	Sperm Oil, per Cent	Graphite, 10 per Cent., Tallow, 90 per Cent.	Cataract Cutting Compound, per Cent	Mineral Lard Oil, per Cent.	None, per Cent.	Machine, per Cent.
0·425in. Diameter of Tap Hole. 75 per cent. Thread.							
Per cent. of breaking strain	15·9	16·5	16·9	18·9	19·9	29·9	34·2
Breakages in tests	None	None	None	None	None	14	15
Quality of thread cut	Smooth	Smooth	Smooth	Smooth	Smooth	Rough	Torn
0·410in. Diameter of Tap Hole. 90 per cent. Thread.							
Per cent. of breaking strain	--	23		25·1	36·5	60·2	68·5
Breakages in tests		None		None	None	50	71·3
Quality of thread cut	—	Smooth	--	Smooth	Smooth	Rough	Torn badly
0·400in. Diameter of Tap Hole, 100 per cent. Thread.							
Per cent. of breaking strain	—	35·5		41	57·5	71·8	100
Breakages in tests	-	None		None	None	66	100
Quality of thread cut	—	Smooth but with tops torn	—	Slightly rough with tops torn	Smooth but with tops torn	Torn and partly stripped	Torn and wedged so as to prevent tap cutting through

NOTE.—By multiplying the above percentages by 10, the actual average power required in inch pounds may be obtained.

Referring in Table II. to the sperm oil column, it will be seen that the decrease of 0·015in. diam. from a 0·425in. to 0·410in. hole required only 65 additional inch-pounds in power, or an average of a little over 4in.-lbs. per 0·001in., while the decrease of 0·010in. from 0·410in. to 0·400in. required 125 additional inch-pounds increase in power, or an average of 12·5in.-lbs. per 0·001in.

KÖRTING'S FUEL-INJECTING APPARATUS FOR INTERNAL-COMBUSTION ENGINES.

FUEL admission valves for internal-combustion engines consuming liquid fuel are now frequently avoided by the use of fuel storage ducts. These are passages which, between the injection periods, become automatically filled with oil, which is injected into the combustion space at the proper moment by

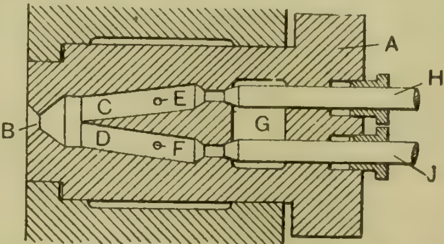


FIG. 1. KÖRTING'S FUEL-INJECTING APPARATUS FOR INTERNAL-COMBUSTION ENGINES.

admitting air under pressure into the duct behind the oil. When two or more of such storage ducts have been used for injecting the same or different fuels, they have been operated by compressed air controlled by a single valve, the opening of which determined the simultaneous admission of the air behind the oil in each duct. The accompanying illustrations show

several designs of apparatus, the invention of Messrs. Körting Bros., Linden, near Hanover, for injecting fuel in an internal-combustion engine having two or more such fuel storage ducts for the same or different fuels, the novelty consisting essentially in the provision for each storage duct of a separate, controlled compressed air supply. The invention may be applied in more than one manner; for instance the separate fuel storage ducts and the corresponding compressed air ducts may open into a common injecting nozzle, or there may be a separate injecting nozzle for each fuel storage duct and corresponding compressed air duct. In the latter case it is particularly advantageous to construct all the injecting nozzles in a single piece of the apparatus, in which they may be arranged either side by side or co-axially, in order that the same or different fuels may enter the combustion chamber at substantially the same place even though separate ducts are used.

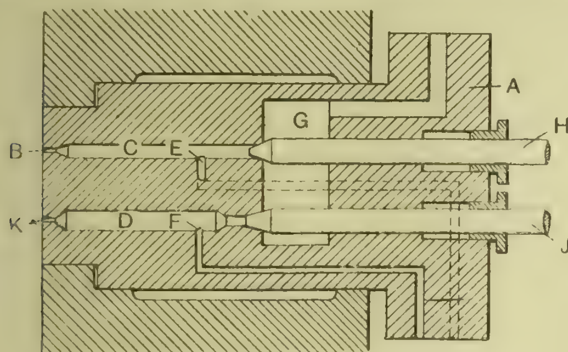


FIG. 2.—KÖRTING'S FUEL-INJECTING APPARATUS FOR INTERNAL-COMBUSTION ENGINES.

Fig. 1 shows an injecting nozzle common to several oil fuel ducts and compressed air ducts; Fig. 2 a modification in which there are separate injecting nozzles situated side by side; and Fig. 3 a modification with separate injecting nozzles situated one within the other, the several ducts being comprised in one piece of the apparatus in each case. In the piece A, Fig. 1, are two oil storage ducts C and D into which the oil enters, preferably from below, through bores E, F. For the purpose of storing the oil, the ducts C and D are made in the form of a shallow V, the bores E and F opening at the angle. The compressed air is introduced through a duct firstly into the chamber G, whence it passes into the oil storage ducts C, D through ports controlled by the adjustable spindles H, J thus injecting the oil which happens to be in the ducts C and D into the combustion chamber of the engine through the common nozzle B. The ducts C and D may be either for

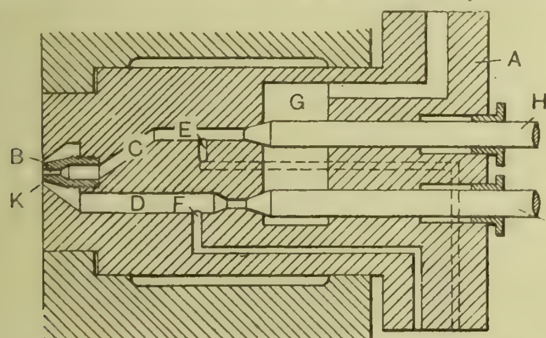


FIG. 3. KÖRTING'S FUEL-INJECTING APPARATUS FOR INTERNAL-COMBUSTION ENGINES.

the same oil or for different oils; in the latter case one oil will be of an easily ignited kind and the other of a more difficultly ignited kind, and the spindles H and J may be so adjusted that for ensuring ignition, the more easily ignited oil is first injected into the engine and immediately thereafter the more difficultly ignited oil.

In the construction shown in Figs. 2 and 3 there are separate nozzles B and K for the oil storage ducts C and D; these nozzles, however, are arranged in the same piece A; those in Fig. 2 being side by side and those in Fig. 3 being so arranged that the nozzle B is co-axial with the nozzle K and is surrounded by the latter so that K is an annular nozzle. For the purpose of obtaining the best possible atomising of the oil there may be arranged suitable atomising devices in the ducts C, D.

THE USE OF POWER GAS FOR HEATING PURPOSES.*

BY MR. D. R. WILSON.

THE works in which power gas is used for heating purposes are comparatively few in number and are often situated either in the country, where coal gas is not available, or in non-manufacturing towns, in which no reduction in price is allowed for gas used for manufacturing purposes; they are, however, also met with in large towns. The purposes for which the gas is used appear to be chiefly:—

(1) In letterpress printing works for heating melting pots on linotype machines and stereo hot presses;

(2) In brass finishing works for heating lacquering stoves;

(3) In various works, such as bookbinding, box-making, &c., for heating glue pots;

(4) In laundries, and shirt collar and clothing factories for heating hand irons and various types of ironing machines.

Plant. — The systems of heating may be distinguished as "suction" and "pressure" plants. The chemistry of the process is the same in both instances, namely, air and steam are passed together over heated anthracite with the formation of "semi water gas," but in the former, air is drawn through the generator by suction from the gas engine cylinder, the steam being supplied by water allowed to drop on to the heated hearth of the generator, whilst in the latter, superheated steam, produced from a boiler, is mixed with air and injected into the generator. In both instances the gas is purified as far as possible by being made to pass through a series of scrubbers.

Suction gas can, of course, only be produced in conjunction with a gas engine, whilst pressure gas is often used for heating purposes only, the motive power in the factory being derived from a steam engine.

Suction gas on leaving the generator and scrubbers is under negative pressure, in which condition it is used for power purposes. For heating, however, it must be compressed to a pressure of 6in. to 12in. of water, and further, this compression should be carried out in such a way that the pressure of the gas remains constant, irrespectively of the amount consumed at any moment. This is a matter of great importance, since if the pressure of the gas is allowed to vary, while the volume of air used for its consumption at the burners remains constant, incomplete combustion, with the consequent formation of carbon monoxide, will be the inevitable result.

Constant pressure is ensured by means of a special form of regulator, consisting generally of a positive blower† for converting the gas from negative to positive pressure and a spring valve fitted to the gas pipe on the positive pressure side of the blower; when the pressure exceeds a certain limit, which can be adjusted by altering the tension of the spring on the valve, the valve is opened and a certain volume of gas escapes by a return pipe to the negative pressure side of the blower. When the limiting pressure is again reached, the valve closes and no further escape ensues.

In this form of regulator, it will be seen that the action of the valve and consequently the gas pressure depends on (1) the pressure exercised by the spring, and (2) the pressure of the gas before compression. If s be the pressure exercised by the spring and p_1, p_2 the pressures of the gas before and after compression,

$$p_2 = s - p_1.$$

Now for p_2 to be constant, one of two conditions must be fulfilled: either s must be very large compared with p_1, or p_1 must be constant. The former condition cannot usually be fulfilled since the final pressure would become excessive. Probably the latter holds approximately true where the load on the engine is fairly constant, but where this is not so the pressure p_1, and accordingly p_2, may vary within considerable limits.

With a view to overcoming this difficulty a modified form of regulator is used in some places, in which the final pressure is made practically independent of the initial pressure owing to the enormous difference in the areas of the surfaces exposed to the two pressures.

In some suction gas plants a different form of regulator,

* Appendix to the Annual Report of the Chief Inspector of Factories and Workshops for the year 1911.

† A positive blower is one so constructed that the higher pressure is independent of the initial pressure of the gas.

namely, the gas holder form described below under pressure plant, is adopted with certain modifications.

Pressure (or the so-called Dowson) gas is usually produced for the sole purpose of heating, though in a few instances it was utilised also for a gas engine.

In this system the gas remains under positive pressure, so that no compressor is required as for suction gas. To keep the pressure constant, whatever the quantity of gas consumed, a special form of automatic regulator is adopted, consisting of a gas holder of a size corresponding to the quantity of gas consumed, to the top of which is fixed a projecting arm connected by a cord to a weighted valve on the inlet pipe. Whenever the gas consumption falls, the pressure in the holder tends to increase and the bell rises; when this occurs the lever of the valve is raised and the supply of gas shut off; as the bell falls again the weight on the lever causes the valve to open and gas is readmitted.

Composition of the Gas.— The composition of the gas varies considerably according to the relative proportions of steam and air, the temperature of the anthracite, and other factors. The following may be taken as the approximate composition of the purified gas, free from moisture:

Constituent.	Percentage by volume.
Hydrogen	18 to 25
Carbon monoxide	25 to 18
Methane	0·5 to 2·5
Ethylene	0·5
Oxygen	0·5 to 0·8
Carbon dioxide	6 to 8
Nitrogen	48 to 50

Properties of Gas.—The gas is much lighter than air owing to the large proportion of hydrogen, and it has therefore, on escaping, a tendency to rise. It is commonly said that it has no smell, but although this may be true of the pure gas, it generally contains sufficient impurities to make its presence felt when it escapes in any quantity. If present in the air, even in small quantities, it causes a peculiar uncomfortable feeling in the throat, and on entering a laundry it is often easy to distinguish by the sensation whether power gas or coal gas is being used for heating the irons, although the actual smell may be masked by that of scorched fibres which is always noticeable in the ironing and machine rooms.

As would be expected, the gas always contains much moisture and is in fact saturated at the temperature at which it leaves the scrubbers; there is therefore a great tendency for water to condense in the gas pipes, and unless care is taken to remove this periodically, there is danger of the burners becoming extinguished and of the gas escaping in large quantities. Impurities in the form of sulphuric acid and other sulphur compounds, which are not entirely removed by the purifiers, are always present, being derived from the sulphur in the anthracite. These attack the metal fittings with great readiness, so that constant attention is needed to prevent leakage from taps and stoppage of the burner orifices. Brass taps are unsuitable, and cast-iron ones should be used. The proportion of impurities naturally varies with the quality of the anthracite, and when the gas is to be used for heating purposes it is important that only the best grades should be used.

Methods of Burning.—Three methods of burning are in use:—

(*a*) The gas is allowed to burn "free" in air without any special supply of the latter. This method is, generally speaking, adopted only for ring burners and similar devices used for heating glue pots, lacquering stoves, &c., which are in such a position that free access of air is attainable. It is unusual to find it adopted in laundries, but in a few instances it is used on collar ironing machines fitted with flues, which increase the draught and the available supply of oxygen.

(*b*) Air inlets are provided in the gas pipe near the point of combustion (Bunsen system). Here the air is supplied by natural draught, and the gas and air are mixed before combustion. This method is sometimes adopted for collar-ironing machines, and more rarely for hand irons, but in some instances it has been found difficult in this way to obtain sufficient oxygen, and it has been superseded by the next system.

(*c*) Air under pressure is forced into the gas pipe at some distance from the point of combustion. This system differs from the preceding in that the air is supplied under pressure, and more opportunity is afforded for the complete admixture of the air and gas. It is being largely adopted, and is the one most commonly found in laundries for both hand irons and machines, and if the gas is burned in an enclosed space, as in collar-ironing machines, it is sometimes the practice to furnish these with an extra air supply providing air for the flame itself. For this method it is necessary to have an extra set of pipes for the air, which is supplied by a small fan. It is of the greatest importance that the pressure of the air should always be in excess of that of the gas; otherwise a back-flow of gas takes place through the air pipes, with the consequence that all the burners are extinguished and there is some risk of an explosion.

Methods of Sampling and Analysis.—As a rule, two sets of samples were taken in each room, one (described as "local") of the actual products of combustion escaping from the machine, and the other (described as "general") of the air of the room as breathed by the worker at the same machine. The analyses for carbon dioxide were conducted by the ordinary Haldane method, a special burette reading to 1,000/10,000ths being used for the "local" samples. For the estimation of carbon monoxide two methods were adopted, the physiological method of Haldane and Lorrain Smith, based on its action on fresh blood, and the combustion method of Haldane, which consists in burning the combustible gases and measuring the contractions that ensue after combustion and after absorption with potash of the resulting carbon dioxide. With the latter method of analysis, when carried out by the small portable form of apparatus, it is impossible to obtain quantitative results with more than two constituents, and for the estimation of the carbon monoxide it was therefore necessary to adopt the following procedure. The samples were analysed both before and after treatment with freshly prepared solution of cuprous chloride in hydrochloric acid, which has the property of absorbing all the carbon monoxide; any contraction therefore resulting after such treatment must be due to combustible gases other than carbon monoxide, and from the difference between the contractions before and after treatment the proportion of carbon monoxide originally present can be calculated. By this method, which gave results in close agreement with the physiological method of analysis, it was found that in most instances large proportions of other combustible gases in addition to carbon monoxide were present.

Discussion of Results.—In works of classes 1 to 3, the gas is usually burnt either on the Bunsen system, or "free" without any special air supply; in both instances the flame is unconfined, and obtains an unimpeded supply of oxygen from the surrounding atmosphere. In these circumstances, incomplete combustion is hardly to be expected, and from the results in Table B it will be seen that the proportion of carbon monoxide in the "local" samples is generally nil, the small quantity occasionally found being probably due to leakage. It is quite otherwise with laundry machines, class 4. In these the gas is burnt in a confined space, such as a cylinder of a collar-ironing machine, and it is evident that not only is incomplete combustion of frequent occurrence, but that it is a matter of great difficulty to ensure complete combustion. In one instance only was the sample practically free from carbon monoxide, whilst in others the proportion reaches to nearly 200 vols. in 10,000. It is rather surprising that the method of burning the gas has apparently little effect in this respect. It would have been expected that when air is supplied under pressure more complete combustion would ensue than when it is supplied under natural draught as in the Bunsen system. The results indicate that there is little to choose between the two methods, but it must be remembered that the conditions under which the samples were taken vary enormously as regards velocity of escape, admixture of air, &c., so that the results of analysis must be regarded as a general proof that combustion is incomplete rather than as a means of quantitative comparison between the various samples. In addition to carbon monoxide, other combustible gases in considerable quantities were usually found in the products of combustion.

Causes of Incomplete Combustion.—The primary cause of incomplete combustion would appear at first sight to be an insufficient supply of oxygen. It would seem, however, that even in an enclosed space such as the interior of the cylinder

of a collar-ironing machine, a plentiful supply of oxygen could be obtained without much difficulty, especially where the air is supplied under pressure. The question therefore arises as to whether incomplete combustion is not due to incomplete mixture of the gas and oxygen, rather than to an insufficient supply of oxygen. It is well known that it is difficult to obtain a homogeneous mixture of gases by admitting them separately and allowing them to pass through the pipe,* and some confirmation is given to this by the fact that when coal gas is used the combustion is far more complete, notwithstanding the fact that five times as much air is required for complete combustion. It is possible that the presence of a large proportion of inert nitrogen in the power gas may have some effect in this respect, notwithstanding that both power gas and coal gas when mixed with air sufficient to burn each completely would contain about the same proportion (about 65 per cent.) of nitrogen. Another probable cause of incomplete combustion is the cooling effect of the cylinder, for it is well known that when a flame is allowed to impinge on a cold surface, some of the combustible gases escape unburnt.

Pollution of the Air.—The air breathed by the workers contains with few exceptions traces of carbon monoxide, and in some instances the proportion amounts to over one volume in 10,000. The highest degree of pollution occurs, as would be expected, in rooms in which no local exhaust for the machines is provided.

Causes of Pollution.—The pollution may be due either to leakage from defective fittings and connections, or to incomplete combustion of the gas in the machines. It is probable that in the cases of acute poisoning, referred to later, both of these causes play a part, but it is obvious from what has been already stated, that with very few exceptions combustion is never complete, and the widespread existence of carbon monoxide in the air breathed is easily explained by this fact. It is unlikely therefore that the presence of CO in the air is habitually due to leakage. The gas pressure seems generally to vary from 6in. to 8in. of water, and this is sufficiently low to obviate any risk of leakage from the connections, provided that they are kept in good condition. Sporadic instances of serious leakage owing to the flame becoming extinguished have, however, been known to occur not infrequently, and to this cause may be traced the occasional outbreaks referred to below. The ventilation of the rooms is, generally speaking, very efficient, as is indicated by the low proportion of carbon dioxide. The rooms are usually small, and, with few exceptions, are provided with mechanical means of ventilation.

Effects on Health.—Enquiry made in many of the places visited has shown that discomfort is comparatively rarely felt by the workers, except occasionally when they first start their employment. Startling exceptions to this, however, have occurred; thus, in one factory all the employés refused to continue their work until the power gas was replaced by coal gas, and in two other factories the use of power gas has been discontinued after a short trial owing to complaints on the part of the workers. Such acute outbreaks have almost universally occurred at a time when the power gas was first installed and were probably the result of inexperience on the part of the operating engineer. It usually happens that the machines have been originally constructed for the use of coal gas, and some time elapses before the necessary modifications required for power gas are completed. The air supply in particular needs careful readjustment, since, for complete combustion, power gas requires about its own volume of air, and coal gas about five times its own volume. When therefore the power gas is first installed, it frequently happens that the air supply is excessive, with the consequence that the gas is being continually extinguished and escape of large quantities of carbon monoxide into the air of the room occurs. Apart, however, from the wholesale discomfort felt on its first introduction, other instances of individual fainting have occasionally occurred in some factories. These may be due, as is often stated, to carelessness on the part of the worker, but it should be pointed out that the impurities in power gas are apt to have a deleterious effect on the metallic fittings, and unless special precautions are taken, stoppage of the burner orifices ensues, with the result that the gas has a tendency to be extinguished at intervals. Another cause tending to bring about the extinguishing of the gas is the deposit of water in the pipes. The gas is always very moist, and the condensed water tends to accumulate in the pipes and obstruct the free passage of the gas. Finally, when the method of combustion entails the supply of air under pressure, it has sometimes happened that the air pressure has fallen below that of the gas pressure, with the consequence that the gas has been forced back through the air pipes, so that all the burners in the room have been extinguished, and, if the air inlet for the supply fan is situated in the room, the mixture of air and gas may even have escaped back against the fan into the room.

Laundries in which Coal Gas is Used for Heating Purposes.—For the sake of comparison, 15 samples were taken from collar-ironing machines in which coal gas, mixed and unmixed with water gas, is burnt. From the results which are given in a table, it appears that, although the products of combustion sometimes contain carbon monoxide to the same extent as those resulting from suction gas, yet as a general rule the proportion is smaller, particularly in the case of coal gas containing no admixture of water gas. Traces only of carbon monoxide were found in the general air of the rooms.

SUMMARY OF CONCLUSIONS.

(1) Power gas is used for heating purposes to a limited extent only, chiefly on laundry machines and for hand irons.

(2) When the gas is burnt in the open with free access of air, combustion is, as a rule, complete and no carbon monoxide is evolved. When, however, it is burnt in an enclosed space, combustion is never complete, even with a supply of air under pressure, and carbon monoxide, together with other combustible gases, is always found in the products of combustion, sometimes in considerable quantities.

(3) Carbon monoxide is almost invariably found in the air of laundries, where power gas is used, in the neighbourhood of the machines in proportions varying from mere traces to over one volume in 10,000. Its presence is probably due to pollution by the products of combustion, and not as a rule to leakage or escape. Whenever causes of fainting or other symptoms of acute poisoning have occurred, it is, however, probable that leakage or escape of the gas has been responsible, the escape being due to the extinguishing of the gas in the machine by one of the following causes:

(*a*) Unsuitable adjustment of the air supply, *i.e.*, supplying too much or too little air;

(*b*) Variation in the gas pressure, owing to an ineffective regulator;

(*c*) Back flow of the gas through the air pipes owing to the air pressure having fallen below that of the gas;

(*d*) Obstruction of the gas pipes by accumulation of water;

(*e*) Partial stoppage of the burner orifices by corrosion by the gas.

GENERAL RECOMMENDATIONS.

(1) Whenever possible, laundry machines in which the gas is burnt in an enclosed space, such as collar-ironing machines, should be fitted with some means of local ventilation. In some instances this is already done, the outlet end of the cylinder of each machine being attached to a flue connected with a transverse duct, to which is attached a small exhaust fan. Simple flues carried through the roof without mechanical means of ventilation are also sometimes found and appear to act satisfactorily.

The local ventilation of gas-heated hand irons is a matter of some difficulty, since the additional tube required is apt to make the iron rather unwieldy. Such a system has been found in one factory only. In some laundries, ducts or hoods connected with a fan are fixed at intervals along the back of the ironing benches in such a way as to draw the fumes away from the irons, and, in default of the more expensive system of local ventilation for each iron, are to be recommended.

(2) The gas supply should be so controlled that the gas pressure remains constant and independent of the momentary demand or the load on the engine (if the gas is used also for driving the engine). This can generally be secured by the use of a suitable regulator, such as one of those already described, provided that the plant is of sufficient capacity.

(3) All fittings and connections should be carefully examined at frequent intervals, and any showing signs of wear should be immediately repaired or replaced. Brass is unsuit-

* This is well seen in the case of petrol gas (or the so-called "air-gas"), in the manufacture of which pure air is allowed to mix with air saturated with petrol vapour. The mixture is non-inflammable under ordinary conditions, and can only be ignited when it is allowed to issue through fine-meshed wire gauze, which is said to have the property of bringing about complete mixture. A few experiments were made to try the effect of a similar method on power gas, but the results seem to indicate that the use of wire gauze makes little or no difference.

able as a material for the fittings, which should all be made of cast iron. The best material for the connections appears to be flexible metallic tubing in which the india-rubber tubing is protected by being covered with metal bands.

(4) Drain cocks should be provided at the lowest points of all the gas-pipe systems, and the accumulated water drawn off each day before the beginning of work. This is already the practice in some laundries.

(5) When the gas is burnt on the separate air supply system, care should be taken to ensure that the air pressure is always at least 2in. of water in excess of the gas pressure, in order to prevent the back flow of the gas.

(6) The relative quantities of gas and air should be carefully adjusted under expert advice so as to obtain complete combustion as far as possible.

(7) The gas should be purified as completely as possible and the best grades of anthracite used, so as to prevent unnecessary corrosion.

(8) Care should be taken that no escape of gas occurs from the burners that have been accidentally extinguished, especially from "pilot lights."

(9) Steps should be taken to make the workers realise that the gas is poisonous, and that any escape may be dangerous and should be at once reported to the engineer.

(10) Finally, it is important that the engineer in charge should be a man of reliability and experience. It too often happens that this is not the case, especially in the smaller laundries, as is shown by the lack of information obtainable as to the gas pressure and other important matters. The impression frequently left is that so long as the gas can be made to burn, no further interest is shown in the plant. Repairs and attention to fittings and connections should obviously be entrusted only to a reliable man.

ROWAN'S VALVE MECHANISM FOR INTERNAL-COMBUSTION ENGINES.

A CONSTRUCTION of valve gear for internal-combustion engines, designed and patented by Mr. L. J. Rowan, 18, Kevelioc Road, Lordship Lane, Tottenham, is shown in the accompanying cuts, Fig. 1 being a sectional elevation of a 4-stroke engine

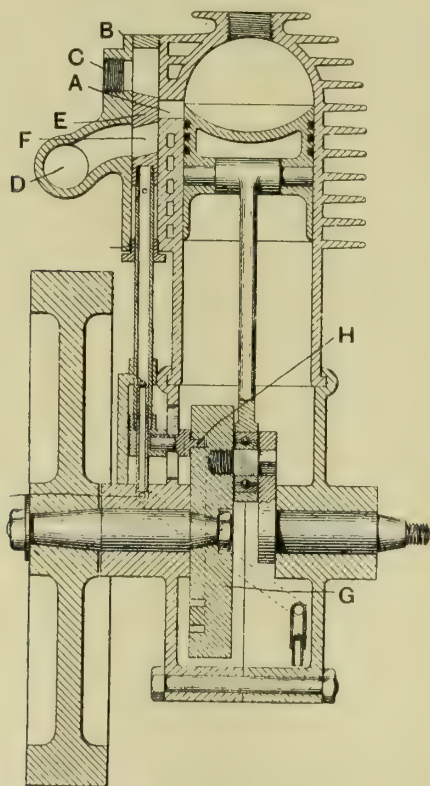


FIG. 1. ROWAN'S VALVE MECHANISM FOR INTERNAL-COMBUSTION ENGINES.

with the gear applied, Fig. 2 a face view of a disc with cam races for operating the slide valve, and Fig. 3 is a sectional elevation and a face view of the slide valve and its box, both constructed to effect a reversing of the running of the engine. A port A is arranged at the top part of the cylinder, this being covered by a box B having inlet C and outlet port D. In this box B is a slide valve E having a slotted opening F so that on its movement it can open the inlet C or outlet D to the cylinder port A or close the cylinder port to both. On the driving crank shaft is connected a disc G, this having on one face two cam races merging together at one part, so that easy communication can be made from one cam race to another and inside the cam race is positioned a curved shoe H so constructed as to easily pass from one cam race to the other, and

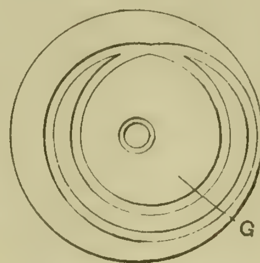


FIG. 2. ROWAN'S VALVE MECHANISM FOR INTERNAL-COMBUSTION ENGINES.

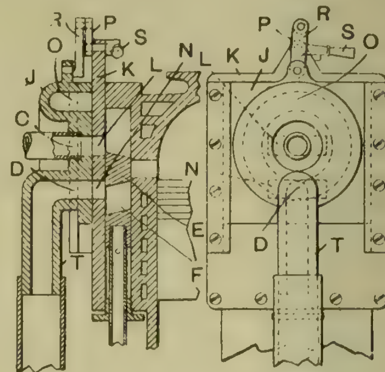


FIG. 3. ROWAN'S VALVE MECHANISM FOR INTERNAL-COMBUSTION ENGINES.

this shoe is connected to the slide valve E by a rod. As the disc G is revolved the shoe H moves round in one cam race, say the outer one, and when it reaches the connection between the two cam races it automatically passes into the inner circular cam race and afterwards back into the outer cam race, so that the slide E is reciprocated in its box B to connect the inlet C or the outlet D or close the cylinder port A as desired, according to the running of the engine.

In the case of a 4-stroke internal-combustion engine with the piston at the end of its stroke, and just going up to compress, the valve E closes the cylinder port A for the full length of the compressing stroke, and after firing until a tenth part of the firing stroke from the bottom, when the slide valve E opens the exhaust D and remains open until the completion of the stroke and also during a full return stroke, then the slide valve E closes the exhaust D immediately and opens the inlet port C to the cylinder port A for admittance of combustible charge, the valve remaining open for the full length of the fourth stroke and closing on dead centre, the compression then taking place on the next outstroke of the piston for a repeat of the operations.

For reversing a 3-way cock or slide J is employed to alter inlet to outlet. This slide covers a plate K provided with holes L, N, which plate is equivalent to the wall of the box B and the holes L and N equivalent to the inlet C and outlet D. This slide J is provided with an inlet C, an outlet D, and an auxiliary outlet O leading to the outlet D and is connected to the plate K by a lever P and rod R so as to raise and lower the cover. In the position shown in Fig. 3 the engine is running in the same way as in Fig. 1, but to reverse, the lever P is actuated by the handle S and the slide for the exhaust O is lowered to coincide with the hole L and the inlet C to coincide with the hole N, thus it will be seen that the inlet and exhaust are reversed and consequently the engine reversed in its travel. The slide is provided with a tube T on the exhaust D, which tube telescopes in the exhaust tube during the movement of the cover J.

The Delhi Pillar.—One of the features of Delhi is its famous iron pillar, and analysis of some specimens of the metal, which have been obtained by Sir Robert Hadfield, shows the following percentage composition: Carbon, 0·08; silicon, 0·046; sulphur, 0·006; phosphorus, 0·114; iron, 99·72; total, 99·966. The iron percentage was determined, not taken by difference. The material is thus an excellent type of wrought iron, and the lowness of the sulphur percentage indicates that the fuel used in its manufacture and treatment, probably charcoal, must have been very pure. The metal contains no manganese, which is rather remarkable, since that element is usually present in wrought iron. It may be added that the specific gravity of the metal is 7·81.

THE WORKING OF ELECTRICAL COAL-CUTTERS.

A correspondent of "The Times" Engineering Supplement makes some interesting observations on some of the difficulties experienced in the working of electrical coal-cutters in collieries. It cannot, he says, be denied that there has been a certain amount of trouble with electric coal-cutters, which has, to some extent, lessened the favour with which they have been received, and proceeds to show that in a good many cases such troubles are due, not to the essential disadvantages of the machine itself, but rather to incorrect application and, in some cases, positive carelessness in use. It is, he adds, a counsel of perfection to say that electrical machinery in a colliery should be treated with the same amount of care and consideration which it receives cn the surface, inasmuch as the type of labour to be found in a coal mine is often less skilled than that found on the surface, and, in addition, the machinery has to be operated under different conditions as regards position, comfort to the workmen, and adequate lighting for inspection. Hence breakdowns are almost inevitable, but they could be considerably reduced in numbers were due regard paid to the proper conditions of using the machines. To deal first of all with one difficulty which is often experienced in connection with coal-cutting machines of the disc type, it has been found that many breakages of shafts have occurred, and also the fuses of the circuit controlling the motor blow to such an extent that there is a tendency to strengthen them unduly. In a good many instances these troubles are due to the fact that the men who run these machines are usually paid by the number of lineal yards that they cut, and this piece work system has the disadvantage that the machines are often run to their utmost capacity. Forward feed of these machines is of course given by means of a haulage rope on a drum which is shortened by means of a ratchet feed and pawl device on the drum, and what often happens is that an attempt is made to get over more ground in a given time by increasing the number of teeth taken by the ratchet at one stroke. Moreover, where pressure of work is kept up to this great extent, insufficient attention is often paid to the proper supporting of the material which has been undercut by sprags or wedges, and the result is that before the coal-cutting disc has proceeded very far along its travel the weight of the coal which has been dealt with is allowed to come upon the cutter wheel, and the friction then becomes so enormous that the strain on the shaft is large enough to break it. An examination of such shafts after fracture frequently shows that they have really been twisted into two pieces, and in some cases where the rate of cutting has been forced in this way, not only one, but several shafts have been broken in a single shift. This difficulty has, of course, engaged the attention of colliery managers and attempts have been made to deal with the matter by imposing penalties on the drivers of the coal-cutting machines who unduly force the machines, but it is obvious that unless the men are caught red-handed it is very difficult to convict them of any improper use of their machines. Here then is a typical cause why electric coal-cutting machines sometimes suffer from a bad name, as the men will naturally endeavour to throw blame on the machine they are handling in order to save themselves.

The blowing of fuses in the gate-end boxes which feed the coal-cutters, the writer proceeds, is due to much the same reason. The tendency to force the pace produces carelessness in the proper support of the coal cut, and in addition there is a danger that the men do not keep the undercut well cleaned out, especially when the machine is cutting on the floor level. Another trouble which frequently occurs is that in order to get as much paying work done as possible in a given time the drivers are apt to postpone the change of cutters in the cutting gear as long as possible, and consequently these soon get very blunt and therefore more power is required from the motor to keep the gear running at the same speed. The action is rapidly cumulative, and before long the fuses blow in order to protect the motor. It cannot be too strongly insisted upon that, when working in coal of average hardness, the cutters should be changed at least once for every 20 yards cut, and a man should be constantly kept at work cleaning out the undercut with a long flat shovel. In connection with this cause of trouble, it may be interesting to note that a device has been recently introduced for releasing the ratchet pawl on the haulage drum so as to interrupt the feed and thus allow the machine to rest in its position until the cutter has churned itself free. This device is useful in preventing a good deal of blowing of fuses, and, quite apart from the time saved owing to the fact that when a fuse blows it has to be replaced, a somewhat tedious process in the dim light of a colliery working, it avoids what is really a dangerous thing in a fiery mine—namely, the blowing of a fuse, however well protected it may be from the surrounding atmosphere. Another point, he says, which should be remembered, both by electrical designers who specialise in mining machinery, and by those who are too apt to condemn the electric coal-cutter, is that all such machines while in action are resting on a purely temporary base, and are kept from shifting only by means of struts or guys. The machines are subjected to very heavy working, often of a violently fluctuating nature, depending on the nature of the work at the moment and the material they have to cut, and hence it is inevitable that they should be subjected to a very heavy mechanical vibration. The effect on the motor armature and commutators is that during operation when the windings are hot there is the danger of open circuits being formed in the windings and connections of the commutator. It is often not convenient or possible to change the armature during the time in which it is actually required for cutting, as the holding up of the machine for the time necessary to effect a proper change involves a considerable loss in the output of coal for that particular section, and therefore a practice sometimes adopted when this trouble develops is to cut out the faulty coil and to bridge the commutator segment. The machine is then allowed to run in this condition until it is possible to bring the armature to the surface, where the repair shop is usually situated, and here a new piece of wire is joined to the coil and put back into the commutator and resoldered. The running of an armature in the condition described does not do it any good, and thus one more difficulty is added to those which an electrical installation has to contend with. Yet another point may be mentioned as showing the rough and ready condition in which colliery electrical plant is often kept. The natural consequence of open circuits and bad insulation is that the commutator is subjected to sparking effects which cannot be done away with at once, and the result is that the metal is often badly pitted. To turn up a commutator in order to take out the marks every time this happens would be a slow and sometimes costly expedient, as it would involve the keeping of a certain number of armatures for coal-cutters for replacing while repairs were being effected, and hence it is not an unknown thing to find that the commutators in coal-cutters have been filled up with litharge if very badly pitted instead of being turned up.

The position of an electric coal-cutter in operation is at all times purely temporary, and in addition to vibration this very often leads to other difficulties. For example, it very frequently occurs that the machine is cutting on a rising face, and as a result it is not uncommon to find that oil runs or leaks out of the bearings, so that the windings get saturated with the oil, which rots the insulation, and finally causes them to give out. This trouble has been the cause of a great many breakdowns of coal-cutters, and has proved a matter of serious difficulty. One way to remedy the matter to a great extent is to drill a small hole in both ends of the motor casing so that should the motor be tilted in either an aft or a fore direction the oil penetrating into the inside of the casing will drain out. It is evident that this does away with the flame-proof properties of the motor casing to some extent, and this is a most important consideration, as it is of course essential that a coal-cutter motor should be entirely enclosed in order to prevent any chance of explosive mixtures of gas and air in the mine from getting inside the casing. But it may be pointed out that as a matter of fact there are so many joints about an electric motor, as often constructed, each one of which is liable to be not altogether gas tight, that even an enclosed motor as now constructed cannot always be described as a practically gas-tight arrangement, and the addition of two small holes of the nature described above does not to any very great extent add to the danger already present, and it certainly has the advantage that it does

away with a lot of trouble in removing any oil which may collect.

One of the greatest difficulties in using coal-cutters is the fact that as the cutting goes on the motor proceeds further and further away from the gate-end box, and that the flexible cable which feeds it must perforce lie along the ground between the box and the machine. In this position it is frequently lying on an uneven surface, and is liable to be seriously injured by surrounding operations; and in order to overcome this difficulty armoured cable is very often used. The use of armoured trailing cables for coal-cutters is, however, not altogether satisfactory for many reasons. For example, it is found to be extremely difficult to coil up into anything like compact form, owing to its stiffness, and the result of trying to do this is to produce kinks which rupture the insulation, causing short circuits. In addition, it is not at all uncommon to find that the armouring has become rusted, owing to the water in the mine. Eventually the armouring breaks, and it then becomes impossible to earth the machine properly unless a special earth wire is bound up with the main current-carrying conductors in the cable itself. Further, it is a very difficult matter to make an efficient joint with armoured cable, and before very long the piece of cable becomes useless for its purpose. It is therefore valuable to mention that a new type of trailing cable has been adopted in a good many collieries and has given very useful results. It consists of heavy braided twin concentric conductors, protected on the outside by a heavy sheath of the same material as is used for manufacturing cab tyres, and this material makes a good cushion to protect the conductors from falling stones, colliers' boots, shovels, drills, and other external objects. Moreover, the cables are comparatively easy to repair should there be any trouble, inasmuch as when the braiding rots or wears the bad places are put right again by simply wrapping them tightly and closely with tar band, and, after this, serving them with Stockholm tar. The earth wire in this case is, of course, carried inside the sheathing, forming an auxiliary conductor laid up with the main power conductors of the trailing cable.

The points that have been raised, says the writer, though not exhaustive, sufficiently illustrate the special conditions attending colliery practice to demonstrate the fact that not only is special design rendered necessary in order to make the machine strong and efficient under the severe conditions to which it is subjected, but also that the system of overhaul and maintenance in a colliery has to be of a very thorough and searching nature. The continued increase in the use of electric coal-cutters is a sure sign of the great advantages which have been obtained by the use of these machines, and in spite of the difficulties and breakdowns which from time to time occur, there is no doubt that electric power in this connection has been the means of largely increasing the output of the colliery and of doing away with a very difficult and dangerous form of manual labour.

Imperial "Wireless" Stations.—A White Paper has been issued containing a copy of the agreement between Marconi's Wireless Telegraphy Company, Ltd., Commendator Guglielmo Marconi, and the Postmaster-General, with regard to the establishment of a chain of imperial wireless stations, together with a copy of the Treasury minute thereon. The minute summarises the negotiations between the Imperial Government and the Marconi Company, eventually resulting in a decision that a chain of stations connecting the United Kingdom with Australia, viâ India, and with South Africa, should be established in the first instance, the installations to be erected in England, Egypt, East Africa Protectorate, South Africa, and Singapore. The Australian Government finally decided not to take part in this agreement, but to proceed independently with the erection of a station in connection with the Imperial wireless chain. It is intended that this station shall be constructed without delay, and that it shall communicate direct with the Imperial station at Singapore. The main provisions of agreement may be summarised as follows: Sites will be provided by the Postmaster-General at the stations mentioned, the company will provide the installations. The Postmaster-General may require them, in addition, to erect buildings and prepare foundations for each station on repayment terms without profit.

INDUSTRIAL AND TRADE NOTES.

W. F. Stanley & Co.—Messrs. W. F. Stanley & Co., of Great Turnstile, Holborn, the well-known makers of mathematical and scientific instruments, have opened a branch at 68, Queen Street, Glasgow.

Swan & Hunter's New Shipyard at Southwick. Rapid progress is being made with the laying out of the new shipyard at Southwick for Messrs. Swan, Hunter, & Wigham Richardson, Ltd. It is expected that the yard will be ready for occupation in about two months' time.

The "Valiant" Steam Fire Pump.—Messrs. Merryweather, Greenwich Road, London, send us a catalogue showing the miscellaneous applications of which their "Valiant" steam fire pump is capable, owing to its portability and power. These, as the illustrations prove, are much greater than most people think, and combined with the intrinsic merits of this self-contained piece of apparatus explain its popularity and success.

Exhibition of Aerial Locomotion at Paris.—The fourth exhibition of aerial locomotion will be held this year in the Grand Palais, Champs Elysées, Paris, from October 26th to November 10th. Copies of the regulations (in French) governing the exhibition, containing form of application for space, may be obtained by British firms on application to the Commercial Intelligence Branch of the Board of Trade, 73, Basinghall Street, London, E.C.

New Armoured Cruisers. The British Admiralty has asked for tenders from eight private shipbuilders for six armoured cruisers of high speed. The cruisers are to have machinery to develop 40,000 h.p., and are to be ready to pass into commission in June, 1914. They are to be smaller than the corresponding German cruisers, but faster. Two others are to be placed in Government dockyards, making eight in all.

Extension of Colville's Steel Works.—Messrs. David Colville and Sons, Dalzell Steel and Iron Works, Motherwell, are making extensive additions to their plant and works, which when completed will increase the output by 2,000 tons of steel per week. Several acres of ground have been taken in, and new smelting furnaces are to be erected and bar and plate mills of large dimensions laid down. The extension is expected to be completed by the beginning of next year.

Wages in the Scotch Iron Trade.—The following intimation has been made to Messrs. James C. Bishop and James Gavin, joint secretaries of the Scottish Manufactured Iron Trade Conciliation and Arbitration Board, by Mr. John M. MacLeod, C.A., Glasgow: "In terms of the remit, I have examined the employers' books for May and June, 1912, and I certify the average net selling price at works brought out is £6. 10s. 3·64d. per ton." This means an increase of 2½ per cent. in the wages of the workmen.

Oil Fuel for the Navy; An Egyptian Depot.—The Lords of the Admiralty are not to wait for the conclusion of the promised enquiry into the whole problem of oil fuel for the Navy, over which Admiral of the Fleet Lord Fisher will preside, to learn something practicable in regard, at least, to its storage. An agreement has, it is reported, been come to between the British and Egyptian Governments, for a large depôt is to be established just east of Alexandria for the storage of oil fuel, suitable and ready for storage purposes. This depôt will be under the administration of British officers, and tenders will shortly be invited for the building of a number of fast steamers capable of distributing the fuel at short notice in the Eastern Mediterranean and the Red Sea.

Metal Filament Lamps.—In a pamphlet issued by the Allegemeine Elektricitats-Gesellschaft, some of the methods of constructing the drawn wire lamp, and also some of the points of difference between the drawn wire and pressed filament lamps are explained. In the latter a number of separate filaments are employed, produced by the pressing process, their ends being welded electrically to a wire frame. In the former the filament, produced by drawing the metal through diamond dies, consists of a continuous wire wound on a frame or spider. Tests carried out with the two types are stated to show, in the case of 16-c.p. wire lamps, an average strength of 17·8, as against 3·0 for those with pressed filaments, while in the case of 50-c.p. lamps the figures are 23·2 and 5·8, respectively.

Threatened Closing of Harland & Wolff's Shipyard.—In consequence of recent disorders in Messrs. Harland & Wolff's yards at Belfast, the firm on Saturday last issued the following statement: "Matters have now arrived at a crisis in the Belfast shipyard. Owing to the disturbances, the impossibility of carrying on work properly has been growing daily more serious. In view of the brutal assaults on individual workmen and the intimidation of others, several departments in Harland & Wolff's have already been closed down, and in their utter ignorance that their own interests are affected by their folly, the extremists have gone so far as to molest and intimidate specially skilled men responsible for the working of the

power plant. These men, assaulted and intimidated, are gradually leaving off work, and as they cannot be replaced the firm are reluctantly obliged to shut down a considerable portion of the plant, which will affect a still larger portion of the works, and thus gradually the whole establishment will automatically come to a standstill."

Another Moulders' Strike at Sheffield.—Trouble has again broken out among the moulders in Sheffield. This time it is in connection with work at Messrs. Thomas Firth & Sons. All the moulders have come out on strike. There was a large and important meeting of the men last week, when the matters in dispute were fully discussed. It is only a few months ago that a strike was settled which affected all the moulders in Sheffield, and kept them out of work for several weeks. When a settlement was then reached it was hoped that there would be no further trouble in the trade for a very long time. It is understood that the strike relates to the old trouble with the core makers and to the difficulty of determining the boundary line between the two sets of workmen.

Mr W. H. Dick, who joined the Board of Directors of Messrs. Wailes, Dove, & Co., Ltd., Newcastle-on-Tyne, at the end of last year, has now been appointed a manager at their head office. Mr. Dick has for many years been a departmental manager with Messrs. Holzapfels, Ltd. Wailes, Dove, & Co.'s business has largely developed during the past few years both at home and abroad, their most recent achievement (entrusted to their American house) being an extensive contract, the largest in the world ever placed for this class of work, viz., for the coating of 46 pairs of lock gates in the Panama Canal, involving over 3,000,000ft. of surface. The firm have also just secured a large order from Messrs. John Brown and Co., Ltd., Clydebank, for the Royal Mail steamer "Aquitania," now being built for the Cunard Line.

Labour Law in Queensland.—A Bill for dealing with strikes and lockouts was introduced in the Queensland Legislative Assembly last week. The Bill provides for special industrial boards, similar to the Wages Boards. A judge of the Industrial Court may mediate or call a compulsory conference. Any association not observing an award will, by the terms of the Bill, be liable to a fine of £500, an employer to £250, and an employé to a fine of £10. Anyone inciting to or assisting a lockout would be liable to a fine of £1,000, and anyone participating in or inciting to a strike to a fine of £50. Strikes and lockouts are unlawful until a compulsory conference has proved abortive and a fortnight's notice has been given to a registrar, and the latter has taken a secret ballot of employers or employés and such ballot has resulted in favour of a lockout or strike.

Sheet Aluminium.—The British Aluminium Company have issued a leaflet pointing out the advantages of sheet aluminium for spinning, pressing, and similar manufacturing processes. A square foot of 14 S.W.G. sheet aluminium weighs 1·11lbs. and costs 1s. 1½d., while a similar sheet in copper weighs 3·70lbs. and costs 2s. 10d., or in brass weighs 3·56lbs. and costs 2s. 8d. The metal is readily spun on the lathe with wood or metal chucks, and for this purpose, as for pressing, the softest sheet is used, speeds up to 3,000ft. per minute being employed. The sheet may be given a high polish by much the same methods as are employed for polishing brass or German silver; it may be satin-finished by the aid of a fine steel scratch brush running at a high speed; and it may be given a frosted appearance by being dipped for a few seconds in hot caustic soda solution, then washed in cold water and dipped in aqua-fortis.

Spanish Iron Ore Output.—The Spanish production of iron ore for the year 1910 amounted to 8,650,000 tons, which slightly exceeded the output of the previous year, although it was considerably below the record-breaking output of 1907. The output of other minerals included 294,000 tons of pyrites; 8,600 tons of manganese ore, 3,231,000 tons of copper ore, 156,000 tons of zinc ore, 35 tons of tin ore, and 216,700 tons of lead ore. These figures represent an increase over the output of the previous year in all minerals except zinc and tin, the decrease in the output of the former being 7,000 tons, and 1,465 tons in the latter. The pig iron production for the year 1910 was lower than in any year since 1902, and only amounted to 373,000 tons. The production of rolled iron, wrought iron, and forgings was 58,100 tons; rolled steel, 171,600 tons; steel forgings and castings, 11,200 tons. Other manufactures of iron and steel amounted to 16,400 tons.

Shipowners' Responsibility: Important Test Case.—A decision of considerable importance to shipowners in regard to their liability under the Workmen's Compensation Act has been given by his Honour Judge Thomas in the Liverpool County Court. A test case was brought by the dependants of a seaman named Ward against the owners of the steamer "Harrington" for compensation under the Compensation Act. Ward was one of three men engaged on the steamer, and after finishing their day's work they went ashore at Fishguard on pleasure. Returning to the steamer the boat was upset and the three men were drowned. His Honour found that Ward came by his death through an accident arising out of, and in course of, his employment. He found that the men had leave to go ashore. Having left the steamer on business of their own they were not within the Act when on shore, but they once more came within the Act when they returned within the area of special risk connected with their employment as members of the crew of the steamer. He therefore found in favour of the applicant.

Coal Resources of Sweden.—From a summary, furnished by the British Consul at Stockholm, of the report on the coal resources of Sweden which Dr. Edward Erdmann is drawing up for the International Geological Congress, to be held in Canada next year, it appears that the commercial coal existing in workable deposits in Sweden is estimated at a minimum of 106,500,000 tons, though the maximum may be estimated at, roughly, 360,000,000 tons. The most important mines are situated in the north-western part of the province of Skane, between Höganäs, Skelderviken, Hallandsås, Soderasen, Billesholm, and Glumslöf (north of Landskrona) towards the Sound. The formation consists of alternate bands of sandstone, clay, and slate, with coal strata between; only the two lowest strata of the formation are considered to be of commercial value. Dr. Erdmann is of opinion that the importation of coal into Sweden will decrease, owing to the utilisation of waterfalls for the production of power and to the existence of peat and bituminous shale deposits.

Iron and Steel Production of South Russia.—According to recently available figures relating to the iron and steel production of South Russia in 1911, the output of pig iron increased 355,000 tons, having totalled 2,376,000 tons, against 2,031,000 tons in 1910. The pig iron output consisted of 519,000 tons of foundry, an increase of 118,000 tons; 1,788,000 tons of basic and Bessemer pig, an increase of 215,000 tons and 69,000 tons of miscellaneous grades, an increase of 12,000 tons. Of steel ingots there were produced 2,096,000 tons, an increase of 249,000 tons, divided as follows: Open-hearth steel, 123,000 tons; acid Bessemer, 106,000 tons; basic Bessemer, 20,000 tons. The production of finished material showed an increase of 226,000 tons, having attained a total of 1,815,000 tons, against 1,589,000 tons in 1910. The increase affected all classes of finished materials except sheets and standard rails, and these two lines decreased 4,000 and 34,000 tons, respectively. Other classes of finished materials showed gains as follows: Beams, 64,000 tons; merchant bars, 71,000 tons; plates, 40,000 tons; wire, 8,000 tons; and miscellaneous 81,000 tons.

Russian Shipbuilding Bounties.—His Majesty's Embassy at St. Petersburg has forwarded a translation of the law enacted to encourage Russian shipbuilding. The law, which will have effect for 15 years, from January 14th, 1913, grants bounties to shipbuilding firms situated within the Russian empire for merchant vessels built of metal and intended for service in foreign waters or on the River Danube, upon the registry of the vessel at a Russian port, provided the vessel was laid down after the promulgation of the law, *i.e.*, June 18th, 1912. Finland and certain other districts are excluded from these bounties. The bounties are calculated on the registered tonnage of the vessel's gross capacity, and are on a graduated scale, varying, in the case of mechanically propelled vessels from 105 roubles per ton for vessels of 125 tons and less to 65 roubles per ton for vessels exceeding 3,000 tons. The bounty on sailing vessels with auxiliary mechanical propulsion varies from 84 roubles per ton for vessels of 125 tons and under to 52 roubles per ton for vessels exceeding 3,000 tons. Bounties are also to be paid for repairs and the installation of new machinery. After the bounties have been in force for ten years they will undergo an annual reduction of 6 per cent. It is to be noted that the law of July 14th, 1908, respecting the admission, duty free, from abroad of iron seagoing vessels will remain in force until January 14th, 1928.

Employment in June.—The Labour Department of the Board of Trade report that employment in June continued good, and showed, on the whole, some improvement on the previous month and a year ago. The weekly increase in wages during June was larger than the total weekly increase in the previous five months. In the iron and steel, tinplate, and engineering trades employment was very good; on the other hand, the ship-repairing industry in London was much affected by the dock strike. As compared with a year ago most of the principal industries showed an improvement. In the 390 trade unions, with a net membership of 833,940, making returns, 20,698 (or 2·5 per cent.), were returned as unemployed at the end of June, 1912, compared with 2·7 per cent. at the end of May, 1912, and 3·0 per cent. at the end of June, 1911. Returns from firms employing 443,790 workpeople in the week ended June 22nd, 1912, showed an increase of 0·4 per cent. in the number employed, and a decrease of 0.9 per cent. in the amount of wages paid, as compared with a month ago. Compared with a year ago there was an increase of 2·2 per cent. in the number employed, and of 8·4 per cent. in the amount of wages paid. The changes in rates of wages reported for June were all increases, and amounted to £19,900 per week on the wages of 191,000 workpeople. The most important changes affected 130,000 coal-miners in Scotland, 3,650 deputies, mechanics, enginemen, and firemen in Northumberland, 20,000 ironworkers in the Midlands, 5,750 steel millmen, engine-

men, gas producermen, and other workpeople in steel works in Scotland.

Membership of Trade Unions.—An interesting case recently came before Mr. Justice Neville which raised the question as to the power of trade unions to expel its members. The action was brought by a man who was a check-weighman employed at the Kingsbury Colliery in Warwickshire, against a trade union registered under the Trade Union Acts, 1871 and 1876, and which by its rules was open to all persons employed in and about the mines in Warwickshire and in kindred industries. It appears that the plaintiff had been employed as check-weighman, and had at all times since October, 1910, been a member of the association, and paid all moneys due from him to the association under its rules, and was therefore entitled to continue to be a member of the association, and he could only be expelled by a majority of the votes of the members present, to be taken by ballot. In November, 1910, the executive of the association passed a resolution which wrongfully purported to expel him without any notice or charge of complaint, and without any chance being given him of showing cause why he should not be expelled, though the amount of his entrance fee and contributions was returned to him. The plaintiff contended his expulsion was contrary to natural justice. For the defence it was denied that plaintiff had been a member of the association since October 1st, 1910, and in particular they relied on Rule 58, which empowered the council to make by-laws, and they had always reserved and exercised the right of rejecting persons proposed as members who were not considered suitable. It was further alleged that the plaintiff had not acted straight to the association, in that in September, 1909, he obtained possession of certain books and papers and had wrongfully detained and refused to deliver up the same until compelled by threats of legal proceedings. Moreover, the defendants maintained that the association was an unlawful combination within the meaning of the Acts 39 Geo. III., c. 79, and 57 Geo. III., c. 19, and the plaintiff therefore was not entitled to maintain the action. Mr. Justice Neville, in giving judgment, held that the plaintiff had properly become a member of the association on payment of his entrance fee, &c., and that the association had no power to turn him out under its rules, and that the attempted expulsion was therefore illegal. His opinion was that trade unions were not criminal associations, and consequently the Acts of Geo. III. did not apply, for trade unions had been exonerated from their provisions by the Legislature. He therefore allowed the injunction for which the plaintiff asked, with the costs of the action.

Trade Credit in Russian Machinery Trade.—The British Vice-Consul at Karkhov makes some observations on the machinery trade of his district for the year 1911, respecting the giving of trade credit. British manufacturers, he says, are generally far too conservative, mainly no doubt because they have not studied the principles on which their continental rivals do business. It is fighting them with one arm tied when one refuses their most powerful weapon. Provided of course that the giving of credit is in the hands of experienced sales managers, and kept under proper control, such outstanding accounts are regarded on the Continent as a very excellent asset, little below fluid capital in value. Without trade the manufacturing plant becomes dead capital, whereas when business is done as above, the outstanding debts are returned within a reasonable time, and carry 5 to 6 per cent. interest. Moreover, when the manufacturer has not sufficient capital to finance the trade, continental banks, or their London branches, are very willing to advance the money to firms of good standing for the support of this credit. It is not unusual for such credit to be given on open account, as an overdraft; but more often customers' six months' promissory notes, with the manufacturers' endorsement, are taken as a guarantee, these notes being renewable at six monthly intervals up to the termination of the sales credit, in say 18 to 30 months. Thus not only is the trade extended without extra capital, and higher prices taken than is possible with cash payment, but an additional profit is made on the difference between the interest charged to the customer and the bank rate. It is largely on this basis that German industry and German exports have, all the world over, risen to figures such as 30 years ago no Englishman would have thought possible. It is by this method that German exports are still expanding and shouldering out British trade on neutral ground, where the United Kingdom should be able to keep an unchallenged superiority. British manufacturers and British bankers will find themselves forced to adopt the German methods of giving credit for the support of the export trade. If they do not do so, the British manufacturer will find himself elbowed aside when his German competitor sets seriously to work, and the British banker will see profitable banking operations, and especially the discounting of foreign bills, monopolised by continental banks, since banks which discount the manufacturer's notes naturally obtain his other banking business also, and where a bank is largely concerned in financing a manufacturing company it will frequently have a voice on the board of that company and influence the company's purchasing operations.

THE ELECTROLYTIC THEORY OF CORROSION.*

BY WILLIAM R. FLEMING.†

THERE can be no doubt that the presence of acids (chiefly carbonic) has much to do with the rapid corrosion of our iron and steel. Without acids in our air and water the corrosion problem would be less formidable. This, however, is only a quantitative view-point. In attempting to get at the facts concerning the true cause of corrosion we should not allow ourselves to be blinded by mere quantitative ideas. Given pure iron in pure air and water, the fact of corrosion is very small. Likewise, with impure iron in impure air and water, the fact of corrosion is very great. But this does not interest us. We are concerned only with the true starting point of corrosion.

Influence of Temperature on Corrosion.—Experiments were conducted with apparatus shown in the accompanying diagram. The letters I and S represent hollow metal blocks, 1in. by 1in. by 1½in., with a ¾in. hole 1¼in. deep. The samples in all cases received their final polishing on 0000 French emery paper. The metal samples are connected by tubes for the circulation of cold water within them. The purifying train consists of: A, dilute sulphuric acid; K_1, 50 per cent. potassium hydrate; K_2, 50 per cent. potassium hydrate; So, soda lime; (the tube connecting bottle and train extends just to the bottom of the large rubber stopper); Sy, is a siphon; C_1, clamp on purifying train; C_2, clamp on siphon; C_3, large iron clamp for bolting down the rubber stopper.

In experiment No. 1 the genuine open-hearth iron and ordinary mild open-hearth steel were used and showed the following chemical constituents:—

	Analyses					
	C.	Mn.	S.	P.	Si.	O.
Iron	0·01	0·01	0·028	0·003	0·003	0·055
Steel	0·09	0·40	0·080	0·070	0·006	0·014

The bottle (2½ litres) was completely filled with saturated barium hydrate solution, recently boiled and filtered. The large rubber stopper carrying the four condensing tubes (with samples attached), siphon, and purifying train, was fitted tightly and bolted down securely by means of clamp C_3. No air bubbles were visible in the apparatus. The bottle was placed in a cold water bath and heat applied. C_2 was closed, and C_1 opened. The expanding solution filled the tube connecting the bottle and purifying train. Thus all air was expelled, and the necessity of removing carbon dioxide from the apparatus by mere shaking avoided.

Then C_1 was closed and C_2 was opened to allow the expanding solution to fill the siphon. The solution was then siphoned off by opening C_1 just enough to allow the incoming air to bubble through the purifying train at the rate of four or five bubbles per second. When siphoned to the level indicated in the diagram the clamp C_2 on the siphon was tightly closed, and C_1 was left slightly open to avoid undue pressure or rarity of the air in the apparatus. The rubber stopper and all connections were well paraffined. The water in the bath began to boil and cold water was made to circulate through the glass tubes and samples. Water immediately began dripping from the samples.

The experiment was continued 35 days. The water in the bath was boiling every minute during the whole period. Likewise, cold water was circulating rapidly through the condensing system. The temperature of the ingoing water was 4° to 5° C. The temperature of the water leaving the system varied from 10° to 15° C. At no time did it exceed 15°. From this the temperature of the metal samples was presumed to be about 8° to 12° C. The temperature of the pure condensed water vapour on their surfaces was probably but slightly higher. These conditions were maintained every minute during the 35 days.

At the end of the 35 days not the slightest spot of rust or discoloration of any kind was visible on either the pure iron or the steel. Under the samples a ring of rust was formed by contact with the rubber stopper. This, of course, must be disregarded. The surface area of the top and four sides of each sample was 7 sq. in. It is remarkable to think that 14 sq. in. of iron and steel can be exposed for 35 days

* From a paper read before the Cincinnati section of the American Chemical Society.

† Chemist and metallurgist, Newport Rolling Mill Company, Newport, Ky.

to pure air and water combined without developing the slightest sign of a rust spot.

This proves that iron or steel will not rust in pure air and water combined, provided the temperature of the metal does not exceed 15° C. (59° Fah.), and provided the temperature of the pure water condensing on its surface does not much exceed 15°; provided, also, that the pure water which condenses on their surfaces is being constantly renewed. Beyond this, the experiment proves nothing. It simply indicates that pure iron or steel will not rust in pure air and water combined.

Rust Obtained in Pure Water and Air.—At the end of 35 days the source of heat was removed and the apparatus taken out of the water bath. The circulation of the cold condensing water was continued until the barium hydrate solution had reached room temperature. The condensing system was then shut off. In a few hours the entire apparatus had reached room temperature, about 22° C. The metal samples were left covered with pure water, the flat tops completely, the sides with irregularly distributed patches or globules. This same water was destined to remain on the iron and steel until removed by natural evaporation at room temperature.

In 15 hours the steel had developed 33 distinct rust spots and all of these spots were on areas covered with the pure water. The pure open-hearth iron was still spotless. After 24 hours contact with the same water at 22° the steel contained about 50 spots; the iron was still rustless. At the end of 72 hours the water had entirely evaporated from the

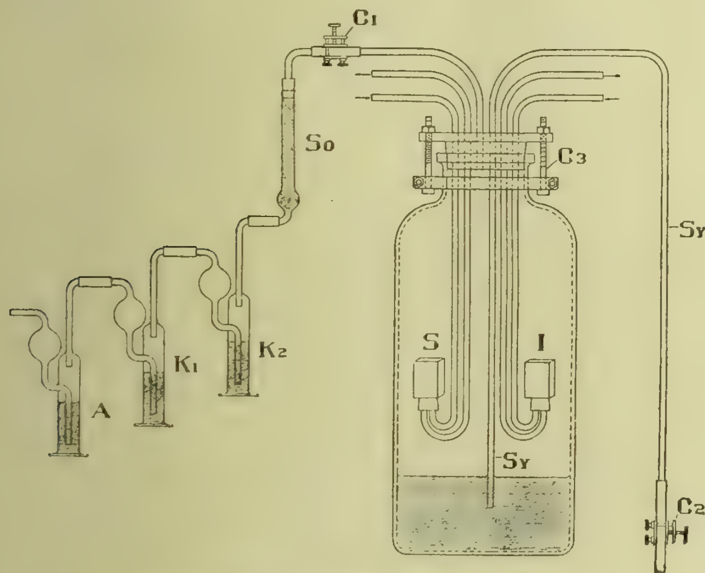


DIAGRAM OF THE CORROSION TESTING APPARATUS.

sides of both metals. The tops were still covered with a thin layer of water. A few new spots had developed on the steel, but no rust had yet appeared on the iron.

At the end of 80 hours the water had evaporated entirely from the tops. Two large glaring spots of rust had developed on the top of the iron within the last 8 hours. More than 72 hours contact with the same water at 22° was necessary to produce rust on the pure open-hearth iron. Less than 15 hours contact with the same water produced rust on the steel.

Iron or steel will rust in pure water and air combined if it is given a chance. The two most important factors which influence the development of rust are: First, the temperature of the metal and of the pure water on its surface; second, the rate at which the pure water is renewed, changed, on the surface of the metal.

The same samples were repolished and the experiment repeated, except that the apparatus was kept in boiling water for 6 days instead of 35. Again, not the slightest sign of a rust spot developed on either sample. Apparatus was then, as the second part of the second experiment, cooled to room temperature as before. Rust developed in almost the same time on both the iron and steel; the iron requiring 90 hours contact with the same water, the steel about 16 hours. The location of the rust spots does not seem to be determined entirely by impurities in the metal, but also by the distribution of the water patches on the surface.

This and a number of other experiments (reported in the paper) clearly demonstrate that pure open-hearth iron and steel will rust, and rust badly, in pure water and air combined, provided the temperature of the metal and water on its surface is sufficiently high. They further prove that rust develops much faster on steel (impure iron) than on pure open-hearth iron. This is in strict accordance with the electrolytic theory.

Acids are only accelerators of corrosion. They are not the cause. The true starting point of corrosion is the solubility of iron in pure water, its electrolytic solution pressure. This property was given iron by nature, and with all our controversy we cannot take away that which nature gave.

General Conclusions.—Pure iron or steel will rust in pure water and air combined, provided the temperature of the metal and pure water is not below 22° C., and provided the same water remains for a sufficient time on the metals.

Rust is developed rapidly if the temperature of the metals and pure water is about 55° C.

Still further increase in temperature results in a decided increase in the rate of corrosion.

The same pure water may remain on the metal for an indefinite period, and no rusting take place, provided the temperature of water and metal is sufficiently low.

In general, pure iron or steel will rust in pure water and air combined, free from all traces of acids. The amount of rust produced is a function of the temperature and of the purity of the iron.

The "acid" theory of corrosion is untenable.

All phenomena observed in these experiments are in perfect harmony with the electrolytic theory.

TURBINE-DRIVEN CENTRIFUGAL PUMPS FOR WATERWORKS SERVICE.*

BY WALTER O. BEYER.

IT is only recently that centrifugal pumps have received the serious consideration of waterworks engineers, although their economy and efficiency have long since been demonstrated for supplying water in large quantities to industrial plants. It is our purpose here to show that the combined fixed charges and operating costs of the rotary unit compare favourably with those of the high-duty vertical triple-expansion reciprocating pumping engines, where the price of coal is not excessive.

The high duty shown by reciprocating engines in waterworks service, involving the pumping of large quantities of water against a constant head, without any great variation in rate, has long and justly been regarded as a supreme achievement. Due to the direct connection of the pump and engine cylinders and to the high efficiency realised in the unit when the proper attention is paid to its valves and packings, the triple-expansion reciprocating pumping engine has been able to develop duties that are unapproachable by rotary units consisting of turbines and centrifugal pumps. However, a careful comparison of the total costs of pumping will show that the balance may be entirely reversed when fuel costs do not exceed a certain price per ton. That is, the high first cost of the reciprocating unit, together with the cost of the foundation required, introduce annual charges for interest, upkeep and depreciation which more than offset the lower duty of the turbine unit.

Of the several types of pumping engines the following are chiefly used for waterworks service: low-duty compound condensing engines, costing with foundations, piping, and appurtenances about $2,300 per million gallons capacity per 24 hours; low-duty triple-expansion condensing horizontal engines, costing about $2,800 per million gallons capacity; cross-compound condensing horizontal flywheel engines, costing about $3,300 per million gallons capacity; and high-duty triple-expansion vertical condensing engines, costing about $4,800 per million gallons capacity. These figures are from a paper presented before the American Society of Civil Engineers, May 17th, 1911, by the late Chas. A. Hague. Since this paper selected the high-duty triple-expansion vertical engine as the only one to be considered in most cases, it is with this type of engine that we shall make our comparison.

* Condensed from a paper read before the American Waterworks Association, Louisville, Ky., June, 1912.

The prices for pumping units given below are, to the best of our knowledge, accurate and include condensers, piping, and foundations complete.

No account has been taken of the greater space required in the buildings for reciprocating units, as a unit volume cost must be assumed which would agree with only one architectural design. Similarly no account has been taken of the greater volume of building required for the larger boiler installation necessary to supply the turbine units, for the majority of existing plants usually have their building proportions determined and a saving could not be made in either room without special complications of no account in this discussion. However, the difference in cost of foundations has been taken into account, because this is an addition in existing buildings and can be easily computed.

In a new station the turbine should be credited with any saving in floor space, buildings, &c., which it may effect as compared with the reciprocating engine, and the reciprocating engine should be credited with the saving effected in the boiler rooms.

In a comparison of this kind, certain assumptions must necessarily be made. We have tried to eliminate as far as possible arbitrary assumptions, and all figures of first cost of apparatus have been taken from, or estimated from recent bids on the two types of machinery under consideration. The first cost per boiler horse-power, for the turbine-driven centrifugal unit we have taken to be $30 complete, with piping, chimney, stokers, &c. (The use of a lower figure would favour the turbine-driven pump as compared with the high-duty engine, but we believe with everything taken into consideration this will prove to be an average figure.) We have assumed the following annual charges against pumping machinery: —

	Per cent.
Interest	5
Depreciation	3
Repairs and supplies	2
Total	10

We have also assumed the following annual charges against the boiler equipment: —

	Per cent.
Interest	5
Depreciation	5
Repairs and supplies	5
Labour on maintenance	2
Total	17

It will be noted in the above that an annual depreciation of 3 per cent. has been taken on the first cost of both the crank and flywheel and turbine-driven unit, equivalent to a life of $33\frac{1}{3}$ years. We have chosen this method rather than one in which the capital charges are figured on a constantly decreasing book value for the pumping machinery and boilers, in order to avoid a complicated method of accounting.

For the reason that fewer data are available on the life of turbine-driven units than on crank and flywheel units, it is possible some objection may be made to this assumption of a life of $33\frac{1}{3}$ years for each machine. However, as in neither case the question of obsolescence has been taken into account, we believe the assumption a fair one. Viewed in the light of possible future development, it would seem that a longer life should be accorded to the turbine-driven unit than to the crank and flywheel unit, as a very thorough canvass of the whole field of pumping equipment does not bring to light any mechanical apparatus which is being developed to compete with the turbine-driven machinery to the same extent as the turbine-driven machinery is being developed to compete with the crank and flywheel machinery.

It further appears that the steam turbine has reached a stage of development such that improvements will appear only as refinements of type, and steam economies can only possibly be reduced sufficiently to render obsolete the present good designs, by better theoretical design and by better steam conditions. The use of high steam pressures and superheat may be expected to gradually obtain further favour in this country as in European practice, where 250° Fah. superheat and 200lbs. steam pressure are not unusual. This, however, entails practically no change in turbines as constructed for present steam conditions.

Fuel costs are based on a boiler efficiency of 65 per cent., heat content of 13,000 B.T.U. per pound of coal and 24 hours per day operation. The duties given are on a basis of 150lbs. steam pressure with no superheat. Three examples are taken, based on coal at $2, $3, and $4 per ton. Where coal can be obtained cheaper than $2 per ton the advantages of the turbine-driven pump are more clearly marked.

TABULATION "A"

8,000,000 gallons per day. Item.	350ft. head Vertical crank and fly-wheel, triple expansion, 150,000,000 duty, 3–125 h.p. boilers.	491 water h.p. Steam turbine, centrifugal, 105,000,000 duty, 3–175 h.p. boilers.
Cost of pumping unit	$72,000	$16,000
Int., depreciation, &c., 10 per cent.	7,200	1,600
Cost boilers	11,250	15,750
Int., depreciation, &c., 17 per cent.	1,915	2,680
Labour, 3 shifts, engines	2,700	2,700
Labour, 3 shifts, boilers	1,800	1,800
Total int., dep., &c., and labour	13,615	8,780
Fuel cost, $2 per ton	7,467	10,700
Fuel cost, $3 per ton	11,129	16,100
Fuel cost, $4 per ton	14,934	21,400
Total annual cost, $2 per ton coal	21,082	19,480
Total annual cost, $3 per ton coal	27,744	24,880
Total annual cost, $4 per ton coal	28,549	30,180

TABULATION "B."

8,000,000 gallons per day. Item.	280ft. head Vertical crank and flywheel, triple expansion, 165,000,000 duty, 3–225 h.p. boilers.	981 water h.p. Steam turbine, centrifugal, 120,000,000 duty, 3–300 h.p. boilers.
Cost pumping unit	$120,000	$26,000
Int., depreciation, &c., 10 per cent.	12,000	2,600
Cost boilers	20,250	27,000
Int., depreciation, &c., 17 per cent.	3,440	4,590
Labour, 3 shifts, engines	2,700	2,700
Labour, 3 shifts, boilers	1,800	1,800
Total int., dep., &c., and labour	19,940	11,690
Fuel cost, $2 coal	13,570	18,630
Fuel cost, $3 coal	20,335	27,945
Fuel cost, $4 coal	27,140	37,260
Total annual cost, $2 coal	33,510	30,320
Total annual cost, $3 coal	40,275	39,635
Total annual cost, $4 coal	47,080	48,950

TABULATION "C"

40,000,000 gallons per day. 200lbs. steam pressure. Item.	300ft. head 275° Fah. superheat. Vertical crank and flywheel, triple expansion, 223,000,000 duty, 3–350 h.p. boilers.	2,120 water h.p. 28·5 in. vacuum. Steam turbine centrifugal, 193,000,000 duty, 3–400 h.p. boilers.
Cost pump	$210,000	$55,000
Int., depreciation, &c., 10 per cent.	21,000	5,500
Cost boilers	31,500	36,000
Int., depreciation, &c., 17 per cent.	5,360	6,100
Labour, 3 shifts, engines	7,200	7,200
Labour, 3 shifts, boilers	5,320	5,320
Total int., depreciation, &c., and labour	39,480	24,120
Fuel cost, $2 coal	23,265	26,800
Fuel cost, $3 coal	34,897	40,200
Fuel cost, $4 coal	46,330	53,600
Total annual costs, $2 coal	62,475	50,920
Total annual costs, $3 coal	74,377	64,320
Total annual costs, $4 coal	85,810	77,720

It will be noted that the point at which the total annual costs are equal for the eight million gallon crank and flywheel vertical unit and the eight million gallon turbine centrifugal

unit is when coal costs $2.91 per ton. Also for the twenty million gallon vertical crank and flywheel unit, and the twenty million gallon turbine centrifugal unit, the total annual costs will be equal when coal costs $3.25 per ton. Above these prices for coal, the reciprocating unit has the advantage and below these points the rotary unit has the advantage on the basis of these calculations.

We believe that it can be assumed safely that the development of pumping machinery in the future will be along somewhat the same lines as the development of power-producing machinery. At the present time one of the most noticeable features in the development of power machinery is the increasing favour with which larger units are being adopted. In large electric station work five years ago, the ordinary size of unit was from 10,000 kw. to 15,000 kw. Now, not only in European practice, but also in American practice, 25,000 kw. units are being installed in the large stations. There are two reasons for this development, the first being the continual endeavour to obtain better economy, not only in actual steam consumption, but in capital charges, including first cost, buildings, real estate, &c. The second reason for the development along this line comes from the fact that engineers of to-day seem to have more initiative than formerly, and where before the development of a 15,000 kw. turbine would have seemed an impossible task, now the installation of 25,000 kw. turbines is becoming a matter of course.

We have assumed that there will be progress along this line in waterworks pumping machinery and that installations of very large units will be made in the future. We have evolved a comparison between two units of the types under consideration, each having a capacity of 40,000,000 galls. per 24 hours, against a total head of 300ft. This comparison is based on utilising the greatest range of steam temperature which the best modern practice has established as commercially practicable, and which at the same time is not too intensely theoretical. We refer here to European practice in which steam pressures of 200lbs., 275° superheat, and 28·5in. vacuum are successfully and commercially utilised. Especially important in this connection is the item of high vacuum, since in the case of waterworks pumping engines large quantities of water are always available for condensing purposes.

Extremely large capacities and high heads present no difficulties, nor disproportionate costs in the construction of steam turbine-driven centrifugal pumping units, since it is an inherent characteristic of the centrifugal pump that the larger the capacity the greater the efficiency for a given head.

There is practically no development necessary on the turbine to take advantage of these conditions, as the turbine of almost exactly the same characteristics that would be necessary for this installation is now in successful operation in hundreds of power-producing plants. We have had to assume no steam consumption, as this is a matter of test, and practically have had to assume no pump efficiencies, as we have taken the minimum which we know can be obtained on this size pump.

Further, the turbine is well adapted to take advantage of the improvement in steam conditions, as mentioned above, and reciprocating engines can also be designed as to take advantage of the initial and terminal conditions favouring high economy.

The results of this comparison are shown in table "C." It is apparent from these tables that the point at which the two curves of overall economy of the two units cross is at a cost of approximately $8.80 per ton for coal.

It would therefore appear that the field of these large capacities at high heads for ordinary coal costs belongs to the turbine-driven centrifugal pump exclusively.

In conclusion, if the above data are correct—and it has been our sincere endeavour to present only such figures as are fair for both types of machines—it would seem that the steam turbine centrifugal pumping unit must be conceded a place of primary importance in the field of waterworks engineering.

New Design of Naval Airship.—The £20,000 included in the Supplementary Naval Estimates for the construction of an airship represents the money to be spent during the current financial year on a new airship, to be built by Messrs. Vickers, Ltd., at Barrow, to replace the one which was wrecked on being launched at Barrow last year.

THE INNER STRUCTURE OF SIMPLE METALS.*

BY SIR J. ALFRED EWING, K.C.B., LL.D., F.R.S.

IN attacking the question of what is the inner structure of metals, the microscope is our principal weapon of research. During the past twenty years or so it has taught us much about simple metals, much also about the constitution of alloys. But its powers are limited, and we find ourselves brought up against an absolute barrier beyond which the microscope cannot go. We want to know what are the ultimate particles of which a metal is composed, how these particles are arranged, and why they so arrange themselves. To these questions the microscope is unable to give us anything like a complete answer; and when we attempt to penetrate beyond the region in which we can accept it as a guide, we do so only by the help of such light as may be perceived by the eye of the scientific imagination.

My intention is first to remind you briefly of some of the things that the microscope has taught us regarding simple metals, and then to go on to some more or less speculative considerations based on that knowledge. I propose to confine myself definitely to simple metals—that is, metals which behave as pure metals behave, leaving untouched the large and complicated subject of the alloys. Alloys present complexities that would only distract attention from the particular points which I wish to bring before you. Without those complexities we shall find the matter difficult enough.

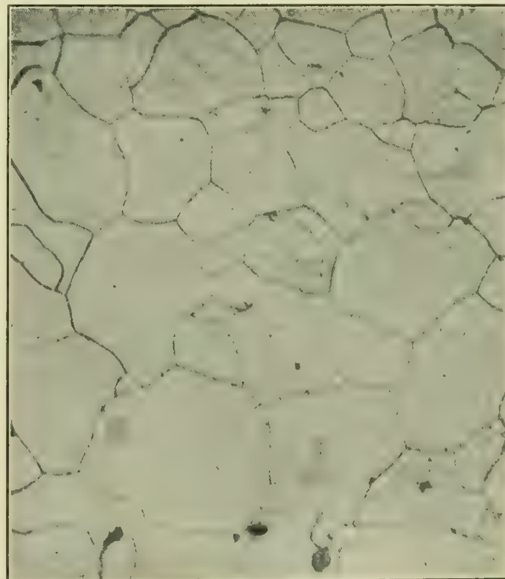


FIG. 1.—BAR SWEDISH IRON AS ROLLED. Magnified 150 diameters.

Some apology is due to the experts in the audience for presenting facts with which they are already familiar, but probably the audience includes some who are not experts, and in any case it is convenient to recapitulate a little of our positive knowledge before entering the region of speculation.

Generally speaking, when we wish to apply the microscope to the examination of metallic structure, we begin by polishing the surface of the metal so as to remove those inequalities which would embarrass the use of the microscope, especially at high powers. As Dr. Beilby showed in the admirable May Lecture† he gave last year, the process of polishing itself affects the constitution. It makes the metal on and near the surface entirely different in character from the metal within. It produces, according to his view—which, I think, is now generally accepted—an amorphous layer in contradistinction to the crystalline structure which, as we shall presently see, is revealed when that amorphous layer is removed. Consequently what we have first to do after polishing is to remove the superficial layer before we can really see the normal characteristics of the structure, and the usual manner in

* Lecture delivered before the Institute of Metals, May, 1912.

† G. T. Beilby, "The Hard and Soft States in Metal," "Journal of the Institute of Metals," No. 1, 1912, Vol. VII., pp. 5—43.

which that layer is removed is by a light chemical attack, a slight etching with an acid or some other substance. Occasionally we may resort to other means of removing the layer. An interesting method which is sometimes available is to heat the metal sufficiently to make the surface layer sublime away.

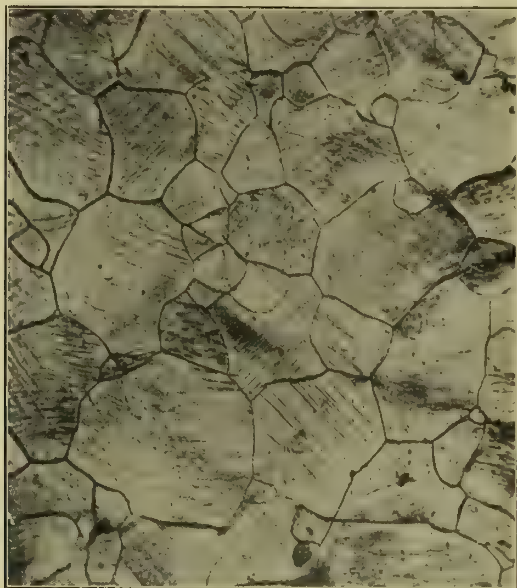


FIG. 10.—SAME SURFACE AS FIG. 1 AFTER STRAINING IN TENSION, SHOWING SLIP BANDS.

When we lightly etch the surface of a metal, what do we see? In general we see an appearance such as is illustrated in Fig. I. This is a microphotograph taken by Dr. Rosenhain of part of the surface of a bar of Swedish iron, magnified 150 diameters. A very similar appearance is presented by other metals. The surface is seen to be composed of a large number of separate grains, irregular both in size and shape, and also irregular as regards the character of the boundaries. Sometimes these are straight and sometimes curved. The shapes of the grains are as irregular as the counties in a map of England; their boundaries depend, like those of the counties, on historical conditions, as we shall see by-and-bye.

Suppose now that we carry the etching a little further (Fig. 2). We discover that the grains can be distinguished

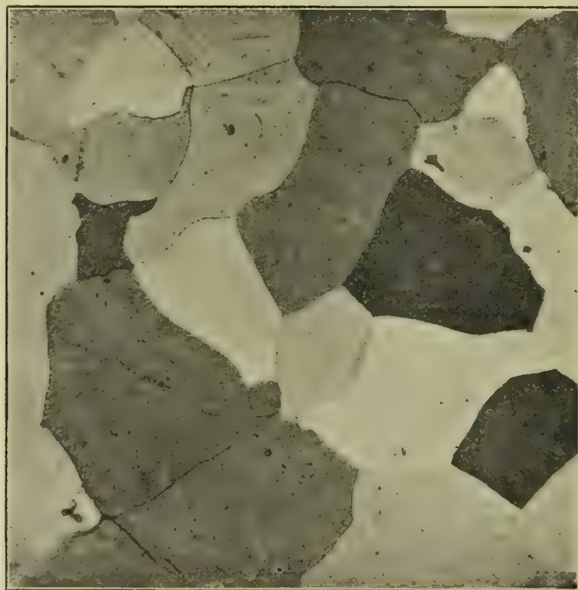


FIG. 2.—NEARLY PURE IRON, ANNEALED IN HYDROGEN AND DEEPLY ETCHED. Magnified 100 diameters. Vertical illumination (Rosenhain.)

not merely by these irregular boundaries. A difference of texture begins to manifest itself between one grain and another; some grains are very bright, some are more or less dark, and some are very dark. If instead of illuminating the surface directly from above, as is the case in Fig. 2, we throw the light from one side, we discover that the same grain which appears bright under one condition of illumination becomes dark under another. Compare Fig. 3 with Fig 2.

These are two photographs, for which I am indebted to Dr. Rosenhain, showing the same part of the surface of one metal* under two different conditions of illumination. In Fig. 2 the light comes directly from above; it strikes the surface perpendicularly, and is reflected up into the microscope. In Fig. 3 the same grains are illuminated by light coming from one side. It will be observed that there is no difficulty in identifying the same grains in both; and that grains which are very bright under the first illumination become dark under the other. If we move the source of light to another side, or turn the specimen round, so as to alter the direction from which the light falls upon it, we find the grains vary in brightness in the most remarkable manner, sometimes flashing out brilliantly and sometimes becoming almost entirely dark. This is true of all metals. These photographs are of iron, but we find gold, silver, copper, lead, and so forth, exhibiting precisely the same general characteristics.

Examination of the etched surface under a high power shows that this difference of texture is really due to a multitude of little facets or tiny plane surfaces in each grain which are causing the general surface of the grain to reflect light in a particular manner. They are acting like a multitude of

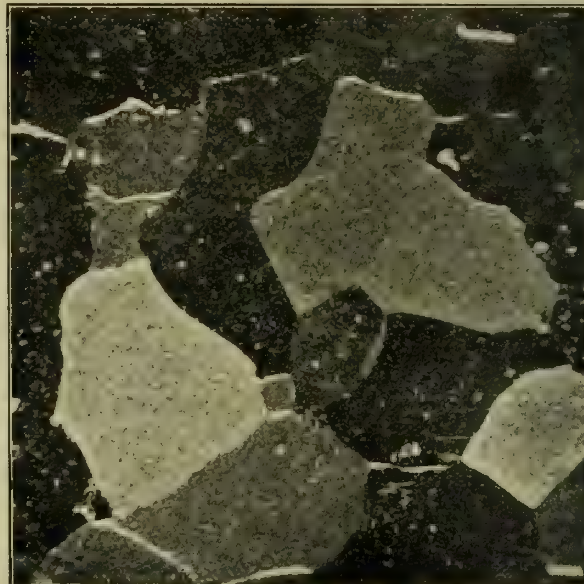


FIG. 3.—SAME SURFACE AS FIG. 2, BUT WITH OBLIQUE ILLUMINATION.

little mirrors all facing one way. These facets are parallel in any one grain, but have different inclinations in the different grains.

In Fig. 4† we have a photograph of a grain of iron, not very deeply etched. A part of a single grain occupies nearly all the photograph under a power of 800 diameters. You observe that over the grain, here and there, are a number of pits which are clearly geometrical in form; they happen to be nearly square in this particular case. In some places a number of pits have run together, forming a black irregular patch, but in other places you can see the individual pits quite clearly. These pits are formed in the process of etching.

Under more favourable conditions, with deeper etching, the whole surface becomes covered with such pits. Fig. 5 is a photograph published a good many years ago by Mr. Stead‡ which shows very clearly what it is that gives rise to what I have called the texture of the grain. In the former example you had only isolated pits, but in this one the appearance is such as would be presented if we were to take a great mass of brickwork and pick out the superficial bricks all over it, so as to reveal the character of the structure as

* Nearly pure iron (transformer sheet metal) annealed in hydrogen and deeply etched with copper-ammonium chloride. Magnification, 100.

† Ewing and Rosenhain, "The Crystalline Structure of Metals," "Philosophical Transactions of the Royal Society," Vol. CXCIII., 1899.

‡ J. E. Stead, "Journal of the Iron and Steel Institute," 1898. The specimen is iron containing 4½ per cent. of silicon in solid solution, deeply etched.

built up of brickbats. That, in effect, is what happens in the etching of a metal.

I do not know any example which gives a clearer indication than this does of what causes the difference of texture in the surface of these grains, nor one that indicates more plainly the real nature of their structure, as developed by etching.

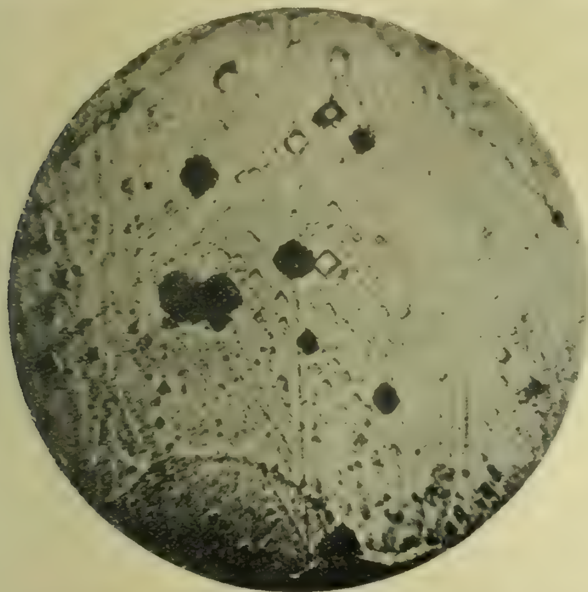


Fig. 4. Iron, showing pits produced by etching. Magnified 800 diameters.

One can see unmistakably how the surface of the grain consists of a multitude of geometrically similar pieces, parallel to one another, so that their corresponding facets are all oriented one way. They are oriented in different ways as we pass from grain to grain, but in any one grain they face one way, and in consequence of that the light which falls on the grain is reflected in a perfectly uniform manner over the whole expanse of that grain, although it is reflected in a very different manner from the surface of any other grain. Over each grain the brightness is uniform, because the little surfaces are acting equally as regards the reflection of light.

From this it is an easy step to infer that throughout the whole volume of any one grain there is an assemblage of

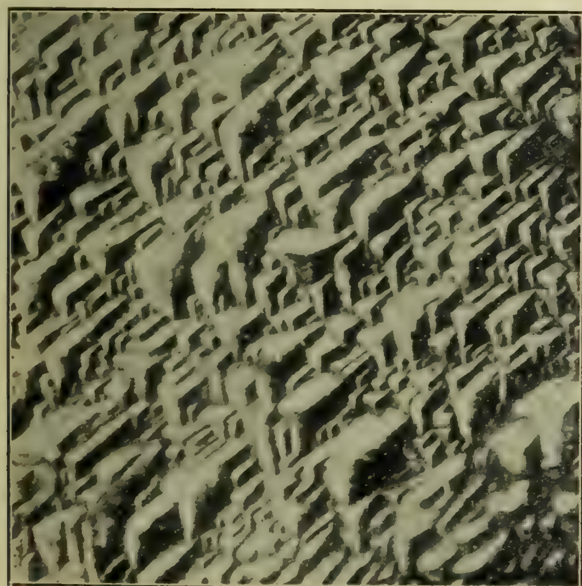


Fig. 5.—Silicon Steel. Magnified 130 diameters (J. E. Stead.)

pieces, which we may think of as the "brickbats" or structural units that build up the grain, all facing one way in the one grain, but facing different ways in different grains. Fig. 6 is another example, a piece of etched tin-plate,* exhibiting the same characteristics. It shows a portion of two grains of the thin layer of tin with the boundary between them, and the difference of brightness is very marked. They are both exposed to the same light, but they reflect different amounts into the microscope. The reason is that the little facets on one are much more favourably directed for the purpose of reflecting the light back to the microscope than are the facets on the other.

One might multiply illustrations all pointing to the same

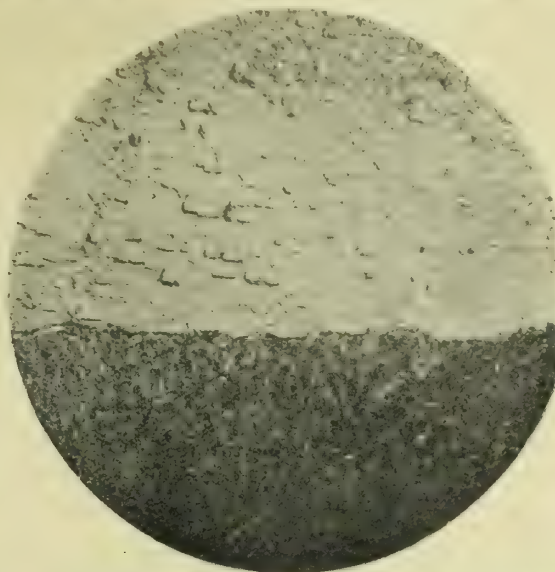


Fig. 6.—Tin-plate, showing boundary between two grains of the tin. Magnified 100 diameters.

fact, namely, that the etching has revealed a definite geometrical structure within the grain by removing, as it were, a few of the superficial brickbats, leaving cavities and protuberances of a geometrical form. The conclusion is simply this, that every one of these grains is in reality a crystal. Notwithstanding the irregularity of the boundary it has the true property of a crystal, the uniformity of internal structure which is the characteristic of a crystal. It is, to use Kelvin's phrase,* a "homogeneous assemblage" of structural units which is put together with greater regularity than any structure built up of definitely formed brickbats.



Fig. 7.—Cadmium, cast on a smooth surface of glass (not etched). Magnified 1,000 diameters.

In some cases we may, without etching the surface, obtain other evidence of the truly crystalline nature of the grains that make up a piece of metal. The next photograph is that of a metallic surface which has never been polished, and never been etched. It is a specimen of cadmium cast against a very smooth surface of glass so that polishing and etching

* Ewing and Rosenhain, "Philosophical Transactions of the Royal Society," Vol. CXCV., 1900.

* Kelvin, "The Molecular Tactics of a Crystal," "Baltimore Lectures," page 602; see also his papers on the "Molecular Constitution of Matter," "Collected Papers," Vol. III.

might be dispensed with. The irregular boundaries of the grains are visible in the microscope, and a slight difference of texture between one grain and another may be discerned in the cast surface without any etching at all. Fig. 7 shows a small part of the surface under a high power, and from it we can see how the difference of texture comes about as a result of certain peculiar markings on some of the grains. Here there are two or three grains only in the field; observe that scattered over them there are little geometrical pits which have been formed in the process of casting. These pits

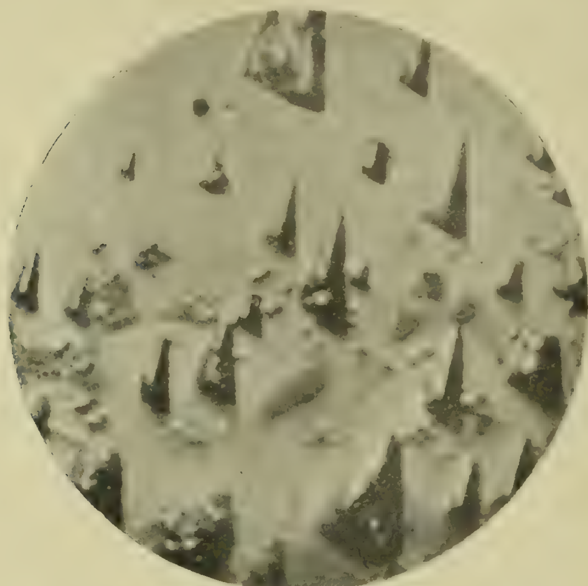


FIG. 8.—CADMIUM, CAST ON A SMOOTH SURFACE OF GLASS (NOT ETCHED). Magnified 4,200 diameters.

are due to an accidental inclusion of particles of gas between the metal while it was solidifying and the smooth glass surface on which it was cast. Whether that gas was air, or gas dissolved in the metal and given out in the process of solidification, I cannot say, but there is no doubt that these pits are formed by little gaseous particles. They are, in fact, negative crystals. The meaning of them is that the whole of the grain is a crystal, and these markings are only the places where the little brickbats have been left out.

Fig. 8 is another specimen of cadmium, also cast against a smooth glass surface, showing in a beautiful manner the same geometrical air pits. This is only a small portion of a single grain; and it may be regarded as rather a *tour de force* of microscopic photography, having been taken under a power of 4,200 diameters. The geometrical markings are pits, not excrescences standing up from the surface.*

The real nature of the grains, then, is that they are crystals, and I think it may make the matter more intelligible if we try to think of the process of crystal building which has resulted in the formation of these grains. How does it come about that the external forms of the grains are so different from the simple, symmetrical forms which we are accustomed to find in isolated crystals? The reason is this. These crystals have grown more or less simultaneously from a number of different centres of crystallisation. The metal as a whole is the joint result of much independent building, such as we might compare to the building of toy bricks by a number of children in a nursery. Suppose we had a number of little fairy children—I say fairies in order that they may be able to disappear as the structure completes itself—a number of fairy children provided with an unlimited supply of perfectly similar brickbats. Place them all over the nursery, not only on the floor, but throughout the volume of the room, and let them start building, not necessarily simultaneously, but capriciously as regards time, and capriciously also as regards place and as regards the positions in which they put down their first brickbats. What would be the result? As each fairy child puts down its first brickbat and goes on adding one to another, a crystal grain will be built. Some may build more quickly than others. What is it that will determine the external form? Simply that each will go on building until the territory is entirely occupied, until the structure which each child is erecting is limited by being brought into contact with the structures of the neighbours. That is precisely analogous to the process that occurs in the solidification of a metal. One may carry the analogy further by thinking of some of the fairy children as having a genius for colonisation, because they stretch out lines which secure for their own building a comparatively large share of territory. Having stretched out these long branching lines, they then proceed in a leisurely manner to fill up the gaps. This is an example of what is called in crystallography dendritic growth. It is a common kind of growth in the actual formation of a solid metal.

In most instances of metal structure, the grains of which the metal is composed are so small that to see them clearly requires the use of the microscope, but under favourable conditions we may have comparatively large grains. There is an example here of a specimen of cast lead which was prepared in my laboratory at Cambridge by Mr. Humfrey some years ago in connection with a research which he was then making on the structure of lead.* It has grains so large that some of them measure 2in. or 3in. across. The piece is lying in dilute nitric acid, which has had the effect of etching the surface and leaving it exceedingly clean, and as I turn it round under a beam of light from the lantern, you will see that the grains darken and flash out bright according to the orientation of the little mirror-like facets of which the etched surface is composed. As a rule we require a microscope magnifying 100 times or more in order to obtain reasonably good photographs of the grains in a metal, but these exceptionally big grains need no enlargement.

Occasionally we find examples of dendritic growth on a large scale in iron castings. Mr. J. T. Milton has been kind enough to send a beautiful specimen of this, a piece cut out of the pipe of a large steel casting showing the crystals in which the metal originally settled itself, dendritic in form, resembling very regular pine trees, and with undisturbed geometrical outlines, resulting from the fact that while those crystals were still growing the liquid metal round about them was drained away by the contraction of the casting below.†

Sometimes evidence of dendritic growth is seen even upon a free surface of a solidifying metal. A dendritic skeleton forms

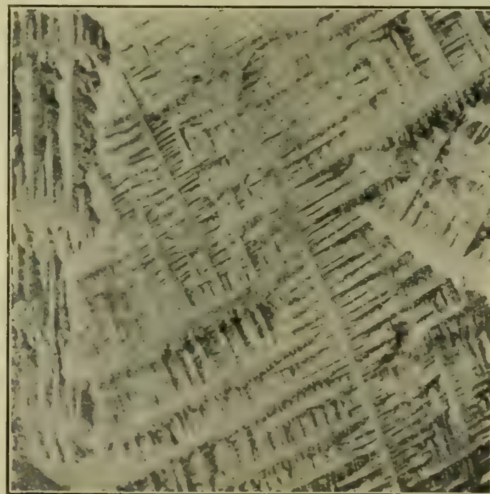


FIG. 9.—SURFACE OF A CAST BLOCK OF ANTIMONY, NATURAL SIZE.

first in the solidification of the surface layer, and this is subsequently thrown into relief by the irregular contraction that results from the cooling of the later growth. Fig. 9 shows a case in point, it is part of the free surface of antimony solidified after melting.

I cannot well exhibit the process of crystallisation going on in an actual metal, but substantially the same thing is readily

* Ewing and Rosenhain, "Philosophical Transactions," Vol. CXCIII., 1899.

* J. C. W. Humfrey, "Philosophical Transactions," Vol. CC., 1902, p. 225.

† A fine example of this dendritic structure in a steel casting is shown by Mr. E. F. Lange in the "Proceedings of the Manchester Literary and Philosophical Society," Vol. LV., 1911.

shown in the lantern by using a salt in solution, which deposits crystals in the same way as they are formed in the solidification of a liquid metal. Take, for example, a solution of sal ammoniac, and, in order not to spend too much time over the experiment, warm it up so that it dissolves some more of the salt, and then run a little of it over a glass plate so as to leave a thin film on the plate. The plate is now put in the lantern, and you see crystallisation begins almost at once. Here we have, as it were, the nursery floor, not the whole volume of the room, and the fairy children are getting to work; they are beginning, some at the edge and some more or less in the centre. Grains are forming at a number of places, and are spreading until they meet. Soon the whole plate is covered with them. I want you to notice how the shape of each is conditioned simply by its meeting neighbouring grains. Each grain is a true crystal, though its final shape is quite irregular. Those of you who are near enough will be able to see that the early stages of the growth of a grain are of the dendritic type; it throws out branches forming a skeleton which is afterwards filled in.

A very important point about metallic structure is that we find true crystal grains not only in metals in the cast state but also in metals in other states, metals which have been wrought, which have been shaped by working even in the cold condition, and also in metals that have been worked in the cold condition and have afterwards been annealed by bringing them to such a temperature that a rearrangement of the grains has taken place. Whether we deal with them in the cold condition or in the annealed condition, we still find the same general characteristics, still the same granular structure, and still the same plain evidence that each grain is in reality a crystal.

Take, for instance, a bar that has been shaped by being passed through a rolling mill in the cold state. One of the photographs already shown (Fig. 4) is part of the transverse section of a cold-rolled iron bar, rolled down from a comparatively large diameter, so that the individual grains within the bar have suffered tremendous distortion in the process of rolling. The greater part of the field is covered by a single crystal. Over its whole surface there are geometrical pits. When it was examined very carefully in the research by Dr. Rosenhain and myself* we found that these pits were parallel all over the crystal notwithstanding the tremendous distortion it had undergone. It was clear, therefore, that the regular parallel grouping of the structural units or brickbats had in some way or other been preserved during the process of severe straining.

The point is further illustrated if you examine in the microscope a specimen of metal that has been broken in a testing machine. Take a fairly plastic metal, such as iron or mild steel, which stretches a good deal before it breaks. If you polish and etch the side of the bar near the fracture, where a considerable amount of extension has taken place, you will find that the metal there consists of grains similar to those you have already seen, but with this difference, that these grains are all elongated in the direction of the stretching. Their shapes may be still very irregular, but there is clearly a predominating greater length in the direction along the bar, as compared with the transverse direction. The stretching the specimen underwent before it broke has elongated each grain, but its granular character persists.

(*To be continued.*)

* "Philosophical Transactions," Vol. CXCIII., 1899, pp. 366-367.

SUPERHEATER FOR WATER-TUBE BOILERS.

THE accompanying illustrations show a design of superheater which has recently been patented by Mr. J. H. Rosenthal, of Messrs. Babcock & Wilcox, Ltd., Farringdon Street, London, E.C., Mr. E. C. Carnt, and Messrs. J. Samuel White & Co., Ltd., Medina Docks, East Cowes, Isle of Wight. Fig. 1 shows the general arrangement and Fig. 2 details of the superheater. The superheater comprises juxtaposed manifolds or boxes A and B, one side of each of which is provided with orifices to receive the ends of U-shaped tubes C expanded thereinto, and the opposite side of each of the manifolds or boxes A and B is provided with handholes adapted to be closed by covers in the usual manner. Some or all of the U-shaped tubes are arranged in pairs, the tubes of each pair being disposed in the same vertical plane and all the tubes being parallel to the axes of the overhead drum E and bottom drums F; one U-tube of each pair being fitted within the space between the legs of the other U-tube of that pair, so that the orifices into which the four upper ends or the four lower ends of two adjacent pairs of tubes are expanded are accessible through one handhole on the opposite side of the corresponding box. Each of the banks of boiler tubes G is sub-divided into two sub-banks or semi-banks, the tubes of the two sub-banks being oppositely curved, that is, curved concavely relatively to each other, so as to afford between them a chamber H of substantially oval formation in cross-section, the major axis of which lies in a plane considerably inclined to the vertical. As shown, the superheater boxes are inclined to correspond with the inclination of the major axis of the oval chamber, and as the tubes fitted within this chamber lie in approximately vertical planes, it will be understood that an extensive staggering of the tube holes is provided and a considerable distance afforded between the holes for receiving the two ends of each U-tube, so as to provide for a large radius of curvature at the bend of the U-tube. Valved pipe connections J and K are interposed between the overhead drum E and the superheater on the one hand, and between the superheater and the main steam supply on the other hand.

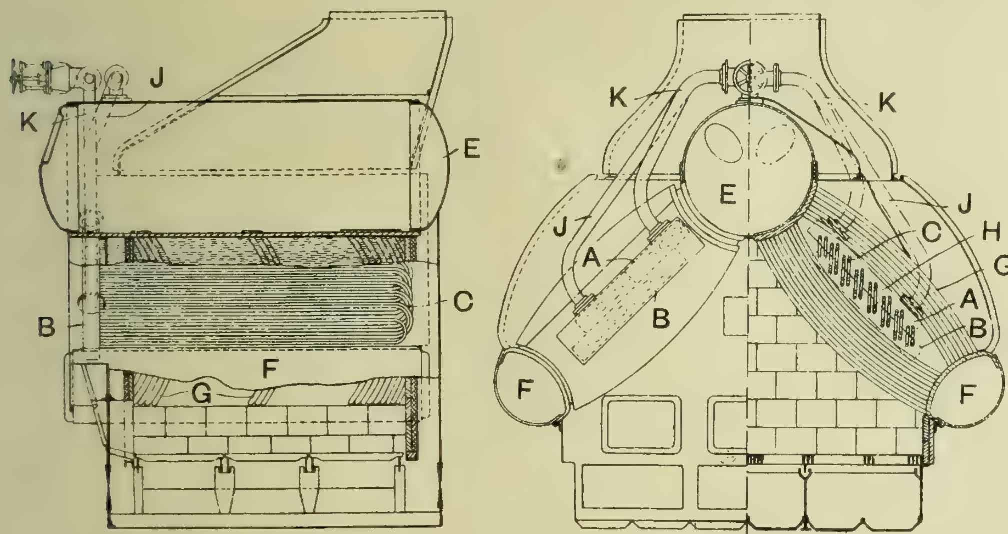


FIG. 1.—SUPERHEATER FOR WATER-TUBE BOILERS.

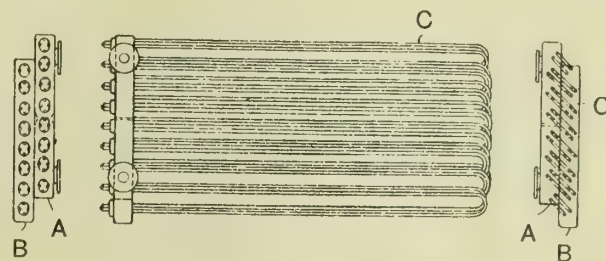


FIG. 2.—SUPERHEATER FOR WATER-TUBE BOILERS.

Battery Tramway-cars.—Three battery-driven tramway-cars are about to be adopted on the line, 15 miles long, at Salt Lake City, Utah. Each car will be driven by 220 Edison nickel-iron cells, to be charged during off-peak loads between 11 p.m. and 7 p.m., and each will be capable of accommodating 50 passengers. The maximum speed on the level will be 45 miles an hour.

INSTITUTE OF MARINE ENGINEERS.

On Saturday afternoon, July 20th, the Institute of Marine Engineers paid a visit to the Instrument Galleries and Circulation Department of the General Post-office. In the Instrument Department in St. Martin's-le-Grand about 3,500 persons are employed, and the succession of large rooms, with line after line of busy operators, gave a vivid conception of the amount of work accomplished. Telegrams in the London district are transmitted on the exchange system, similar to telephone work, the transmitting branch office being connected to the receiving office and the message transmitted direct. For provincial and foreign work, however, the messages are received at the General Post-office and re-directed. Several of the newer instruments were examined in detail, notably the Baudot, duplex system, transmitting the messages at a rapid date, the receiving strips being printed in ordinary type; the Gell, with typewriter keyboard punching out in the Morse code; and the Rotyrer, with extremely light touch. Other extremely interesting machines were shown, such as the instrument by which newspaper matter is transmitted to seven or eight provincial towns at one and the same time; the instrument for converting the Morse code strips into strips of ordinary type, &c. Among recent installations is a number of telewriters, instruments which transmit handwritten messages and reproduce them in facsimile. A time and labour saving device which has been in use for several years is the service of pneumatic tubes through which messages are sent to the branch offices at a rate of about 30 miles an hour. Some time was spent in examining the large collection of instruments, insulators and curios preserved in the museum.

The enormous new reinforced concrete structure in King Edward Street, covering two acres of ground, was then inspected. In this building 1,100 sorters deal with the work, which does not include the provincial letters, these being dealt with in another department. Machines for sorting the letters, &c., into different sizes were examined, and stamping machines were seen at work impressing the postal mark on letters at an almost incredible speed, one machine being capable of stamping 1,100 letters a minute. The intricacies of sorting the letters for the various towns and districts were then explained. In the basement, the manner of dealing with the daily avalanche of letters from the public letter boxes was seen, conveyers on endless belts carrying the baskets to the various sorting departments. It may be remarked that all the machinery is electrically driven. The bag sorting department also is in this section.

The delivery of the bags to the mails, stationed in the yards at the St. Bartholomew's end, is accomplished with the minimum of labour, conveyers and shoots converging there from all directions. In the foreign department were seen letters, some years old, for the lonely island of Tristan d'Acunha, waiting until a British gunboat, by which the letters could be sent, should pay a visit to the island. It is interesting to note that on an average no fewer than 8,000 letters per day are dealt with which are insufficiently addressed, and of these 80 per cent. are correctly delivered. In another department repairs are effected, burst letters sealed, parcels re-tied, &c.

An inspection of the newspaper sorting and stamping department brought a very enjoyable visit to a close.

Lost Coal in Staffordshire.—At a meeting of the South Staffordshire and Warwickshire Institute of Mining Engineers held at Birmingham, Mr. D. E. Parry said it had been estimated that 40 million tons of coal in the South Staffordshire district were in immediate danger of being irretrievably lost owing to submergence. He did not, however, take so serious a view of the position. The coal referred to was not in one area, intact, but was distributed in small and isolated patches throughout the thick coal portion of South Staffordshire. He admitted the coal was lost for the present, but a time might come when circumstances were more favourable for working. Although the output of the South Staffordshire district had seemed stationary for some years, he claimed that developments at Baggeridge, Holly Bank, Aldridge, and Walsall Wood ensured that for a great many years there would be a plentiful supply of coal to feed the industries of the district.

FUEL BRIQUETTING IN AMERICA.

Considerable progress has been made in the development of fuel briquetting in the United States in the last two years, according to Edward W. Parker, in a statement just made public by the United States Geological Survey, though this country still lags far behind some of the European countries, particularly Germany, in this line of industrial activity. In 1909 the production of fuel briquettes in the United States was 139,661 net tons, valued at $652,697, an increase of nearly 55 per cent. in quantity over 1908. In 1911 the production amounted to 212,443 net tons, valued at $769,721, the increase in two years amounting to 72,782 tons, or 52 per cent., in quantity, and to $317,024, or 70 per cent., in value. In Germany the briquetting industry has made extraordinary progress, the production in 1910 being 16,668,605 net tons, and in 1911, 18,554,020 tons.

In Mr. Parker's opinion, more attention should be given to this industry, as on it depends to a considerable degree the utilisation of some grades of fuel which are now wasted or sold at less than the actual cost of production. The reprehensible practice of shooting bituminous coal "off the solid"—a practice notably prevalent in the fields of non-coking coal in the Mississippi Valley—produces an inordinate proportion of slack, which might be made into briquettes.

Some probability of more substantial development of briquetting in the Eastern States is indicated by the recent advance of 25 cents a ton on the domestic sizes of anthracite, and the fact that there is little possibility of any future reduction in the prices of this fuel. In fact, further advances are more to be expected, in view of the rumoured increase in royalty to be demanded by the owners of coal lands in the anthracite region.

It seems reasonable, therefore, to suggest that the utilisation of the small sizes by manufacturing them into briquettes, on which a profit could be made, might be more rational than selling these small sizes, as is now done, for less than the cost of production. The available quantity of raw material of this grade for briquetting is enormous. In 1911 the shipments of anthracite smaller than pea coal amounted to over 20,000,000 gross tons, of which 85 per cent. was obtained in the preparation of freshly mined coal. This 20,000,000 tons was worth not to exceed $30,000,000, but if manufactured into briquettes of egg and stove size at a cost of about $25,000,000 it would have been worth $70,000,000. In other words, the outlay of an estimated $25,000,000, mostly in labour, would have brought a profit of 60 per cent. The enormous culm banks of the anthracite region, monuments of earlier mining methods, contain millions of tons of briquettable coal.

In 1909 the Geological Survey suggested that greater inducement to the investment of capital in briquetting could be offered if investors were assured of a regular supply of suitable binding material. The manufacture of coke in by-product ovens, which yields coal-tar pitch that makes an excellent binder for briquettes, has shown notable progress in the last two or three years, and as the by-product oven is continuing to supplant the beehive oven at an increasing rate, the supply of coal-tar pitch at a reasonably low cost should be assured. In addition to the slack from bituminous, sub-bituminous, and semi-anthracite non-coking coal and small sizes of anthracite, three other kinds of raw material for briquetted fuel are available, namely, lignite, peat, and coke dust.

The Los Angeles Gas and Electric Corporation, Los Angeles, Cal., operates a briquetting plant for utilising the carbon obtained as a by-product in the manufacture of illuminating gas from crude petroleum. The briquettes, or "boulets," make excellent domestic fuel.

The briquetting industry, according to Mr. Parker, has been retarded by attempts to exploit secret binders and processes for which extraordinary and impossible merits are claimed. The pathway of briquetting development is strewn with wrecks that are due to this cause. There is no reason for secrecy in connection with the constituents of patented binders. The field is so large that there is room for everyone to develop the industry in paths laid out by the experience of European countries.

Twenty plants in the United States manufactured compressed fuel in 1911, an increase of 4 over 1909, but 4 of

the 20 plants in 1911 were operated only in an experimental way or for demonstrating purposes. Of the commercial plants, 8 used anthracite as a raw material, 2 used bituminous coal, 2 used semi-anthracite, 1 used refuse from oil-gas works, 1 used peat, and 2 used mixed material. The manufacturers place their products on the market under special names, such as "boulets," "eggettes," "carbonets," "coalettes," and "patent fuel."—"The Iron Age."

THE CLEANING OF STEAM BOILERS.

Mr. W. S. Smith, H.M. Inspector for Dangerous Trades, makes the following observations on the subject of boiler cleaning, which, owing to representations made as to excessive temperatures in which men are employed in cleaning steam boilers, were, he says, made the subject of special enquiry. This, he adds, is not yet completed, but he gives the following report, in which Mr. Warren (Lincoln) deals with what has been already accomplished:—

"In September I commenced an enquiry into the conditions under which the cleaning of steam boilers and boiler flues was carried on, in company with Mr. Sydney Smith in most cases. Up to the present time 32 boilers in 17 factories have been inspected, and sufficient evidence has been gathered to show that in some cases the work is done at a very high temperature. Probably even higher readings would have been observed during the months of July and August, as the recorded temperatures were generally lower as the year advanced. The worst conditions were found usually in Lancashire and Cornish boilers. Very high temperatures were not met with in water-tube boilers. Where specific complaints were made as to conditions of work, it was found that the temperature was not so great as in many of the boilers inspected, but the flues of the boilers, when complaints were made, were generally exceptionally small and the heat would be felt more severely by men working in such confined spaces.

"The usual procedure with Lancashire and Cornish boilers, prior to cleaning, is to blow off the steam two or three hours after drawing the fires, then three hours later to run off the water, take off the man-hole and mud-hole covers, open the flue doors and dampers, and draw air through the flues for varying periods, usually about 12 hours, a process known as 'draughting.' A boiler is usually blown off on Saturday afternoon; where there are no spare boilers, the work of cleaning is commenced early on Sunday morning, so that the fire may be lighted in the evening and steam raised by Monday morning. Where there are spare boilers, cleaning is generally done in the middle of the following week. The flues are cleaned first and the boiler is scaled afterwards; as a rule a boiler is blown off for cleaning every four or five weeks. It is impossible to determine how long a boiler should be 'draughted' in order to obtain a reasonable internal temperature, as in some cases a comparatively low temperature was recorded after 12 hours' 'draughting,' whilst in other cases excessive temperatures were found after 36 hours, though there was no apparent reason for this disparity. In my opinion the only method of determining whether the flues or boilers are fit to be entered is to take the actual temperatures, and in considering what maximum should be allowed, it must be remembered that in the flues the men are working in a confined space in a very dusty occupation, in addition to being in a heated atmosphere; further, that the flue dust is generally at a temperature of over 300° Fah., and the brickwork is often sufficiently hot to burn the leather of the men's boots or may even blister the feet. The flues of Lancashire and Cornish boilers were found to be hotter than the boilers, but the heat is quite dry. In the side flue of one boiler I found a dry bulb temperature of 160° Fah. The boiler was heated by waste gases from a puddling furnace. The neck between the boiler and furnace was broken at 3 p.m. on Saturday and the temperature was taken at 9 a.m. on Sunday. As the furnace had to be relighted for Monday morning it would appear almost impossible to reduce the temperature of such flues sufficiently by 'draughting.'

"Although the boilers were always cooler than the flues, the heat within the boilers was more oppressive, as it was generally humid. In the case of Lancashire and Cornish boilers, wet bulb temperatures exceeding 90° Fah. were taken in two cases, and over 80° Fah. in 10 cases. Leaky valves were occasionally found admitting steam from a boiler in the same range. Such defects can be remedied, but it is not easy to reduce the internal temperature of a boiler further, except by allowing it to stand longer and cleaning the dust out of the flues sooner, if that were possible. In one case we saw a revolving spray of cold water inside a boiler in order to reduce the temperature quickly, where it was desired to enter shortly after blowing off steam; temperatures of 93° Fah. dry bulb and 85° Fah. wet bulb were recorded. Such a method, however, caused an excessive amount of humidity within the boiler, and would be objected to by many engineers as cooling the boiler plates too rapidly. In two Rastrick boilers, wet bulb temperatures of 93·5° Fah. and 88° Fah. were taken; the temperatures of the flues were not excessive, and probably the heat inside the boilers was due to the fact that only one opening, a man-hole at the top, was provided in each boiler. The firm had previously arranged to fit mud-holes at the bottom, which would enable a thorough draught to be obtained during cleaning operations, and possibly reduce the temperatures to reasonable limits.

"Enquiry was made as to the health of the boiler cleaners. Some of the men had suffered from colds and rheumatism, and occasionally the great heat had made them feel sick and dazed, but no cases of pneumonia, respiratory trouble or serious illness were heard of. Some years ago slight cases of lead poisoning had occurred amongst the boiler cleaners at blast furnace works in Cumberland, owing to presence of lead in the iron ore. The boilers are heated by waste gases from the blast furnaces, and lead oxides were carried into the flues, deposited with the flue dust and inhaled by the cleaners. These men were all found to be wearing respirators.

"The question of cleaning boiler flues mechanically is being considered by some firms. If this can be done successfully without the men entering the flues, it might be possible, by cleaning the flues sooner, to reduce the heat within a boiler; the internal temperature would fall more rapidly after removal of the hot flue dust. We have seen two installations of vacuum plant at work cleaning the flues of Lancashire boilers. In these cases the men were inside the flues manipulating a nozzle attached to a flexible pipe. In some cases it might be possible to work the pipe from outside by providing special doors in the brickwork of the flues. Experiments are being made by one firm in this direction, and doubtless if any demand is created for such plants they will be greatly improved."

The Institute of Civil Engineers.—Under the will of the late Sir James Inglis, a former president of the Institution of Civil Engineers, the Institution has just received a legacy of £5,000, to be applied to its new building which is now in course of erection in Great George Street, Westminster. This legacy testifies to the marked interest which Sir James Inglis took in the scheme for rebuilding the Institution, to the cost of which he also, during his life-time, contributed liberally.

The Silent Knight Motor Engine.—Last week Mr. Justice Neville, in the Chancery Division, delivered a reserved judgment in an action brought by Mr. Charles Y. Knight, engineer, Broadwater, Coventry, and Mr. Lyman Bernard Kilbourne, Chicago, against Argylls, Ltd., to restrain an illegal infringement of a patent No. 14729, of July, 1905, for an invention relating to internal-combustion engines known as the Silent Knight engines, and said to have been first used by the Daimler Company. The defendants denied infringement, and set up the defences of anticipation and lack of novelty. His Lordship found that on the true construction of the plaintiffs' specification there was no infringement. An engine made in conformity with the specification would not work at all. The mistake was that the piston had been placed on the wrong side of the engine. Plaintiffs contended that this mistake would be obvious to any engineer, and he would see how it could be corrected, but on the evidence of the defendants his lordship was satisfied that the specification presented to the enquirer a mechanical problem of considerable difficulty, and the solution, which was said to be obvious did not occur to any of the witnesses who were set to solve the problem. This action, said his lordship, was a somewhat audacious attempt to resuscitate a patent from an invention of a very small compass, and by amendment make it cover and embarrass a very large field of enterprise. So far as he was concerned the attempt failed, and the action must be dismissed with costs.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Turbines. Churchill-Shann. 9054.
Means for imparting energy from one body of gaseous fluid to another, and the utilisation of the resulting product. Hart. 11080.
Manufacture of tubing from helically-wound strips of metal. Lawton, Lawton, Cooper, & Cooper. 13532.
Casting metals and metallic alloys. Critchley & Dombrain. 14568.
Apparatus for producing gaseous fuel particularly for use in welding metals. Anderson & Anderson Manufacturing Company. 15537.
Railway points or switches. Brown, Thierwechter, Hahn, & Foot. 15538.
Manufacture of railway axles. Mellor. 15629.
Armoured pipes and pipe joints. Cervenka & Mercurio. 15691.
Machinery for manufacturing nut blanks. Reynolds & Chapman. 15700.
Cutting worm gear. Lanchester. 15811.
Winding apparatus. Thomas. 15885.
Change speed gears. Bond. 15911.
Packing for fluid-tight joints. Corner. 16193.
Machines for making balls for ball bearings. Hoffmann Manufacturing Company, and Schmidt. 16279.
Bearings for internal combustion engines and air compressors. McBain & McBain. 16348.
Speed-controlling devices for engines. Herr. 16362.
Safety hooks for cranes. Dutton. 16783.
Reversing gear for internal combustion engines. Lake. 17688.
Fluid-pressure clutches. Pauilhac. 19134.
Re boring rock drill cylinders. Davidson & Richards. 19181.
Propellers for aerial, marine, and other vessels. Jones. 19378.
Rotary engines. Cummins. 19748.
Variable-speed driving mechanism. Dallison. 21493.
Bucket-chain elevators. Gotuzzo. 21532.
Means for preventing overspeed and overwind in winding engines. Grant, Ritchie, & Co., and McAlister. 21552.
Fluid-pressure engines. Aylward. 21794.
Controlling valves of steam steering engines. Taylor. 22093.
Poppet valves. Pountney, and Rudge-Whitworth, Ltd. 22399.
Screw-making machines. Henn. 22816.
Rotary vacuum pumps. Allport & Lowden. 23181.
Telescopic hydraulic lifts. Gray. 23253.
Exhaust silencers for internal-combustion engines. Dallison. 23259.
Apparatus for the destructive distillations of mineral oils. Laing. 23446.
Belt gearing. Boesner. 23581.
Axle boxes and other bearings. Beadman & Macklin. 24109.
Micrometer measuring attachment for use in reading scales. Pivoda. 25314.
Centrifugal pumps. Coker. 25687.
Combined fuel and air injection devices for internal-combustion engines. Aktiebolaget Wigelius Motorer. 26047.
Apparatus for indicating the level of liquids in tanks. Van Auken. 27383.
Apparatus for measuring gases, vapours, and liquids. H. Liese (firm of). 27467.
Trough conveyers. Gebr. Eickhoff. 27516.
Non-return valves. Maw & Shannon. 28035.
Shaft governors. Bloxam. 28937.
Packing ring. Bergmann Elektricitats Werke Akt.-Ges. 29197.

1912.

Variable speed gears. Elliston & Fell. 793.
Hull for submarine boats. Cavallini. 1315.
Internal combustion engines having rotary distributing valves. Da Costa. 1362.
Carburetting devices for air-gas apparatus. W. M. Still & Sons, Ltd., and Abbott. 1455.
Two stroke cycle internal combustion engine. Viard. 2174.
Apparatus for heating compressed fluid for operating pneumatic and other mechanism. White & Duryea. 3526.
Rotary internal-combustion engine. Bouret. 3545.
Apparatus for automatically regulating the temperature of the cooling water for water-cooled gas turbines. Wedekind. 4351.
Steam generator furnaces. Whittaker. 4662.
Fusion welding. Burnet, and Tudor Accumulator Company, Ltd. 4701.
Acetylene generator for welding plant. Anderson, and Anderson Manufacturing Company. 4855.
Oxygen generator particularly for use with welding plant. Anderson, and Anderson Manufacturing Company. 4860.
Cold-sawing machines. Keats. 5193.
Apparatus for classifying ores. Compagnie D'Entreprises de Lavage de Minerais. 5235.
Sparking plugs for internal-combustion engines. Revault. 6398.
Safety devices for lifts or elevators. Hamilton. 6677.
Oscillatory bearings. Fairweather. 7549.
Furnace bridges. Smith & Rees. 7716.
Travelling grate furnaces. Misener. 8253.
Circulating pressure boiler. Rutter. 9367.
Sight feed apparatus for indicating the flow of liquids. Wilton. 10151.
Valve gears. Kramer. 10204.
Governing and controlling internal-combustion engines. Moore and Ambrose, Shardlow & Co. 11024.
Nut-locks. Jones & Bicones, Ltd. 12084.

ELECTRICAL, 1911.

Methods of and means for changing the frequency of alternating electric currents. Taylor. 8853.
Printing telegraphy. Kinsley. 15559.
Telephones. Killar. 15725.
Senders for electric signalling systems. Brown. 16074.
Electric transportation systems. Seaman, and New Transport Company. 16160.
Arc lamps. Ogilvy-Webb & Reinecke. 16367.
Conduits or casings for electric conductors. Woodhouse. 16489.
Automatic and semi-automatic telephone exchange systems. McBerty. 16869.
Telephones. Gwozdz. 17363.
Control of trackless trolley vehicles. Stevens. 17381.
Interrupters for use in electric ignition systems for internal-combustion engines. Flint. 18701.
Multiple arc lamps. Wetter. 18925.
Magneto ignition for internal-combustion engines. Cambessédès. 19025.
Arc lamps. British Thomson Houston Company. 22548.
Regulation of alternating current dynamos. Siemens Bros. Dynamo Works, Ltd. 22757.
Electrical switches. Terry & Townsend. 22895.
Common battery telephone systems. Aktiebolaget L. M. Ericsson and Co. 23824 and 23918.
Arc lamps. Railing & Angold. 23990.
Dry-battery cells. Rudolphs. 24031.
Dynamos of the compensated type. British Thomson Houston Company, and Neild. 24570.

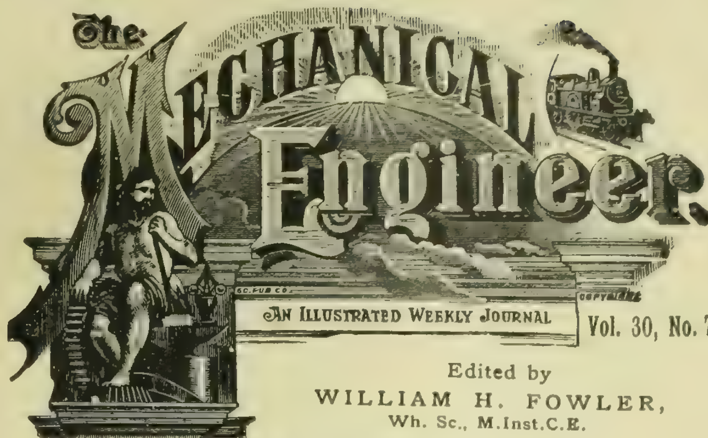
1912.

Electric circuits and fittings therefor. Cave. 1264.
Magneto apparatus for starting internal-combustion engines. Unterberg & Helmle. 2864.
Sparking plugs. Zimmermann & Slaby. 5302.
Detectors for wireless telegraphy. Pickard. 7251.
Electric accumulator electrodes. Pape. 7999.
Electricity meters. Isaria Zahlerwerke Akt.-Ges. 8226.
Arrangements for determining position by means of electromagnetic waves. Thompson. 8559.
Electrolytic process for cleaning metal articles. Langbein Pfanhauser Werke Akt.-Ges. 9609.
Electric signalling apparatus. Street. 9936.
Arc lamps. Weber. 10737.

METAL QUOTATIONS.

TUESDAY, JULY 30TH.

Aluminium ingot	75/- per cwt.
„ wire, according to sizes, &c. ......from	102/- „
„ sheets „ „ ...... „	120/- „
Antimony .... £28/-/- to	£28/10/- per ton.
Brass, rolled	9¼d. per lb.
„ tubes (brazed)	11¾d. „
„ „ (solid drawn)	10d. „
„ „ wire	9¼d. „
Copper, Standard	£77/12/6 per ton.
Iron, Cleveland	58/8 „
„ Scotch	63/9 „
Lead, English	£19/-/- „
„ Foreign (soft)	£18/15/- „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£8/10/- per bottle
Silver	27⅝d. per oz.
Spelter	£26/-/- per ton.
Tin, block	£204/-/- „
Tin plates	14/7½ „
Zinc sheets (Silesian)	£29/5/- „
„ (Stettin; Vieille Montagne)	£29/7/6 „



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Industrial Accidents.

A STUDY of the observations and statistics relating to industrial accidents in the reports of the Inspectors of Factories furnishes interesting reading to those who have time and patience to wade through them. Taking the accident figures as a whole the year 1911 at first sight appears to compare rather unfavourably with the years immediately preceding it. In 1908 and 1909 there was a diminution both in fatal and non fatal accidents, as compared with 1907, but 1910 showed a sharp rise, which was continued last year, when the fatalities again equalled those recorded in 1907, while the non fatal accidents marked an increase of nearly 20 per cent. on that period. This increase, however, appears to be due mainly to a more accurate system of recording injuries and to a greater readiness to claim in respect to them, combined with greater employment arising out of increased population and greater trade activity, for analysis of the non-fatal accidents shows that the increase was entirely in those of a trivial nature, such as burns, scalds, and bruises, while those of a serious character, such as the loss or fracture of a limb or loss of sight, were distinctly fewer, despite the increase in the number of persons engaged. Incidentally the analysis illustrates the difficulty of instituting comparisons between figures and the danger of jumping to conclusions. That accidents are still too frequent is undoubted, but it is impossible to compare the successive annual reports that are issued without feeling that very distinct progress has been made both in respect to safety and sanitation of industrial occupations, and the latter, although less visible in figures of industrial risk, ultimately contributes more to the health and longevity of workers, and succeeds in doing so because it operates in many ways through agencies they cannot control. It is impossible to investigate the causes of personal accidents without being struck with the extent to which workmen contribute to their own undoing. Not only does familiarity breed in them contempt for risk, but they appear to often go out

of their way to seek it; the greatest difficulty, in fact, in designing safety devices for machinery is to make them "fool-proof." Observations to this effect crop up in the various reports. A boy is killed by sheer legs on which he is swinging in his dinner time falling on him; a painter sends away a man who is holding a ladder, which then slips and causes his death; a man is nearly killed through going behind his lathe among some shafting to kill time while another man repairs his machine. Men will persist in doing things they are expressly forbidden to; they will endeavour to put belts on pulleys running at high speed, they will remove guards or fences from saws, emery wheels, and other dangerous things, if it interferes or they think it interferes with their work; girls will wander about amongst revolving shafting with their hair flying loose. It is the same with regard to electrical machinery; safety devices are neglected, obvious precautions ignored. It is useless, of course, to rail at all this, they are only examples of human weakness and liability to err which can be expressed in figures where large numbers of men or women are working for any purpose, and must be reckoned with as a definite factor in the statistics of factory employment. Further, it is not the workmen alone who disobey injunctions designed for safety, as is shown by the list of prosecutions of employers for non-provision of statutory safety appliances and the instances of neglect of reasonable supervision. Saw guards are now compulsory, yet " while it is rare to find one unprovided with a guard," it seems, says the inspector for the south-eastern division, " almost as rare to find one with the guard properly adjusted to the work in hand." This may be due to some extent to the exaggerated claims of manufacturers as to the adjustability of their guards for different sized saws. " One pattern of circular saw guard (it is almost a pity the make is not stated) seems always to be supplied two or three sizes too large, and cannot be set to any useful degree of safety." The fact should be noted, for it is useless to expect the same guard to fit saws which differ by more than a few inches in diameter.

Shafting is as usual a prolific source of casualties, through workpeople approaching it incautiously and getting their clothing entangled. The danger of projecting nuts and studs of couplings, is, however, now better recognised, and in this connection the inspector for the Dundee district mentions a simple and inexpensive way of fencing short lengths of shafting, viz., heavy millboard tubing such as is commonly used for carrying unmounted pictures or drawings. This can be obtained for a few pence a yard, and when split longitudinally can be sprung on the shafting and sealed, and allowed to ride loose or be held by a light wire bracket. Cranes and lifting gear, as usual, contribute largely to the list of accidents, but the percentage due to breakage of ropes, chains, or gear, though the results are serious, is relatively small as compared with those arising from the dislodging of articles carelessly slung. The practice of annealing and testing chains and lifting gear is becoming more general in large engineering and shipbuilding establishments, though in smaller shops a good deal is left to chance, and in respect to wire ropes, it may be remarked that examination is of little use unless the grease with which a rope is covered to protect it from rust is thoroughly cleaned off before the inspection takes place; and further, that the use of large pulleys, by avoiding excessive bending action, materially contributes to the life of a wire rope.

Grindstone and emery wheel failures are frequent in the Sheffield district, no fewer than 86 failures of grindstones and 14 of emery wheels being recorded in 1911. As a careful analysis shows that the greatest number of grindstones burst when the surface speed exceeds 3,500ft. per minute, it is urged with reason that this speed should not be exceeded. Further, stones in stock should not be exposed to the weather, as frost and damp tend to develop inherent defects, while the holes in the centre for the arbor should be round and not square, as the swelling of the wedges sets up severe stresses at the corners. Emery wheels are now run with greater safety than was the case a few years ago, owing to the wheels as a rule being made of better material and being more carefully mounted on the spindle, but several accidents are still traceable to wheels being badly mounted and run at excessive speed. One fatality which occurred while the wheel was having a trial run may be noted, as it shows the danger of running without safety appliances even temporarily. The wheel, 18in. diam., had a tablet attached stating that 1,100 revolutions was the recommended speed and that it had been tested to 1,900. At the trial it was being run without guard, and when the speed reached 1,500 revolutions it burst, and one of the fragments struck the mechanic in charge and killed him.

During the course of the year 1911 particular efforts appear to have been made to reduce the frequency of accidents in foundries. The most frequent cause of these is the spilling of molten metal and the burning of workmen, especially about the feet. The men often contribute to them by their carelessness in carrying metal to the moulds or catching it at the cupola, and it is generally agreed that burns would be less frequent if men wore special boots provided with strips of leather or "spats" over the lace holes to prevent the entrance of metal. It is stated that in some instances the risks of accident are increased owing to overcrowding, especially in shops engaged on piecework, and to the placing of iron plates under the cupola spout or in gangways in certain foundries. The general opinion appears to be that under the cupola such plates are both dangerous and unnecessary and that where used in gangways for convenience of transporting metal they should be deeply checkered to present a rough surface and diminish risk of slipping, and that brick or concrete is a better material. The imperfect lighting of foundries is no doubt responsible for some accidents, especially where there are overhead travelling cranes, and the dirty nature of the work and surroundings makes a satisfactory solution rather difficult, especially in older foundries, which in many cases appear to have been designed as if light were something to be dreaded. The artificial illumination with a ring or star of gas flames perched in the roof and still frequently met with is of little use and in modern shops is being replaced with high-pressure incandescent gas burners or electric light. In big, lofty shops one or two rows of arc lamps near the roof supplemented with filament lamps at the sides seem to provide a satisfactory solution. The arc lamps which give out a bluish-white light, however, should be avoided, as experience shows the light does not penetrate dust fumes or vapour so well as light of a yellowish colour. It may be pointed out that whatever kind of light is adopted, and whether it be generous or limited in quantity, it pays to supplement the illumination by a frequent renewal of limewash on the walls. The diffusion of light in a room so treated is several times as great as in one where the walls are dirty.

In 1909 a detailed analysis was given in the annual report of accidents in cotton-spinning mills with a view to showing the relation, if any, between (1) causation and occupation; (2) causation and hour; (3) day of week and hour; (4) age and occupation; (5) age and injury; (6) age and hours of

work before accident. In the following year a similar analysis was applied to shipbuilding, and the present report gives the similar data with regard to the manufacture of locomotives and automotors. It is necessary to be careful in drawing conclusions from the maze of figures presented in these tables, but there can be no harm if we exercise due reservation in noting their general aspects. Taking the relationships in the order named, it appears that in the locomotive industry that of the accidents reported to certifying surgeons—which may be taken as sufficiently serious to suspend employment—we find the greatest incidence is on men working lathes, with a total of 199. After them follow hammermen and smiths with 149, and then come labourers with 139, fitters with 95, borers and drillers with 84, and planers and shapers with 76, after which come men connected with boiler-making, such as punchers, riveters, and platers with 17, 18, and 4 respectively. These figures give of course only an indication of frequency of serious accident and do not of course differentiate even the latter feature. When we turn to minor accidents which were reported to inspectors only, the figures give again another interpretation, for fitters, who come in for slight bruises as part of the daily programme, head the list with a total casualty figure of 901, after which follow labourers with 601, and then hammermen 373, boilermakers 240, riveters 139, and while turners in the previous classification rank worst stand rather low down with a total of 127. These figures of course only give a rough indication of the comparative risk of different trades because the total number employed is not stated, and in fact go to show how difficult it is to get anything which is really comparable. Turning to the relation between "causation and hour of accident," we seem to get on more stable ground, for the accident rate increases definitely with the time distance from the starting point in the morning: it is comparatively low first thing and increases to breakfast time. After this the rate, starting again at a low level, though not quite so low as at first, steadily mounts up to dinner time, when another cycle begins, the rate steadily mounting up to the evening stopping time. The variation is of the kind which would be naturally expected, and illustrates how fatigue and risk in manual operations—depending for performance on co-ordination 'twixt eye and hand—move more or less on parallel lines. An inspection of the number of accidents from day to day throughout the week does not indicate any pronounced cyclic change such as appears in the daily analysis. The run of figures is fairly uniform, and would seem to show that the night's rest fairly recuperates those engaged in locomotive manufacture and enables them to begin Friday's task with no greater percentage of accident risk than Monday. A uniformity of a similar kind characterises the accident rate from month to month, at all events the differences are too small to permit of any serious deduction being based upon them. The tables giving the relation between age and occupation and age and nature of injury suggests a more interesting analysis, but only permit of imperfect conclusions, because the numbers engaged at any particular age are not stated. Taking the totals, however, as they stand, they support the general conclusion that has been arrived at by actuaries that risk of accident is often coupled with the inexperience and lack of care exercised by the young, and not due so much, as some think, to the lack of agility in old age.

SUGGESTED CLASSIFICATION OF CARBON TOOL STEEL.

BY HENRY OTTO.

On account of the many varieties of steel in the market it is rather a difficult matter for tool foremen to make a correct order to secure the real article needed for their various requirements. My idea would be to standardise the grades of steel and name them in a manner which would indicate the per cent. of carbon contained in each.

I believe if we would make about four classifications we would meet all the requirements for tools used in railroad shops, which should be as follows:—

(1) Should contain 0·65 to 0·75 per cent. carbon.
(2) Should contain 0·75 to 0·85 per cent. carbon.
(3) Should contain 0·85 to 0·95 per cent. carbon.
(4) Should contain 0·95 to 1·05 per cent. carbon.

To be sure we get the per cent. of carbon in the steel we desire, steel received may be referred to our test department for analysis. Workmen not familiar with the per cent. of carbon contained in the steel cannot heat the steel with any uniformity in result.

With the grades that I have recommended we should heat and harden our steel to the temperatures here tabulated:—

Heating for Forgings.

Grade No. 1 should be 1,750° Fah.
Grade No. 2 should be 1,700° Fah.
Grade No. 3 should be 1,650° Fah.
Grade No. 4 should be 1,600° Fah.

Heating for Hardening.

Grade No. 1 should be 1,480° Fah.
Grade No. 2 should be 1,475° Fah.
Grade No. 3 should be 1,455° Fah.
Grade No. 4 should be 1,450° Fah.

Heating for Annealing.

All grades from 1,250° Fah. to 1,300° Fah.

Draw temper of all grades to suit character of work to be performed. As a matter of information I would suggest that the first grade of steel be adopted for use in making pick points, wrenches, pinchbars, crowbars, &c. The second grade to make smith tools, boilermaker tools, track tools, hammers, sledges, cold chisels, chisel bars, &c. The third grade to make general machine-shop tools, counterbores, milling cutters, punching tools, rivet sets, shear blades, machine drills, &c. The fourth grade to make taps, dies, reamers, small machine-shop tools, brass tools, &c.

C. A. Cook, master mechanic, Chicago, Indianapolis and Louisville Railway Company, Lafayette, Ind.: I do not think it would be at all practical to use one standard of steel for the making of the various tools mentioned, but I believe it could be covered by two carbon numbers. For the reamers, taps, drills, and thread-cutting tools, I find that about 0·90 to 1·00 per cent. carbon give the best results; but for rivet snaps and all tools with shanks on to be used in air tools, also punches, dies, and shear blades, where they are subject to shock and beating, a lower per cent. of carbon, say about 0·75 per cent., should be used. I find that I get the best results from tools we make by following those carbon percentages for the two different classes of small tools mentioned.

W. J. Eddy, inspector of tools and machinery, Rock Island Lines, Chicago: The per cent. of carbon that should be used in tool steel for making taps and reamers should be 0·95 to 1·10; for punches and dies, 0·85 to 1·00; for rivet snaps, 0·65 to 0·80. The writer doubts very much whether tools containing shanks used in connection with air hammers should be used in the same class as shear blades. Shear blades should contain 0·90 to 1·00 per cent. carbon, and if rivet snaps are included in this list they should not contain so much carbon.

The Institution of Civil Engineers.—The Council of the Institution of Civil Engineers have resolved to propose at the next meeting the election of Mr. Thomas Coltrin Keefer, C.M.G., of Ottawa, Canada, as an honorary member of the Institution, because of the distinguished part he has taken in the engineering enterprises which have aided so largely the development and prosperity of the Dominion, and on account of the services which he has rendered to civil engineering during his long association with it since his entry into the profession in the year 1838.

WIRE ROPES FOR LIFTING APPLIANCES.*

BY DANIEL ADAMSON.

THE question of the durability of the parts of mechanical structures seems to be strangely neglected by all authorities. A designer has generally the choice of several formulæ for calculating the mere strength of a given member, but usually he has to depend upon his own experience for the correctness of the proportions that will ensure for it a reasonable length of life. The durability of wire ropes in particular is of great importance to all engineers, whether engaged in the design and manufacture of lifting appliances, or in their care and management.

The two most important conditions appertaining to the manufacture and use of steel wire-ropes that affect their durability are:—

(*a*) Quality of material and size of wire.

(*b*) Diameter of pulleys and arrangement of ropes.

(*a*) **Quality of Material and Size of Wire.**—The wire used for lifting ropes is of crucible steel having a tensile strength varying from 80 to 130 tons per square inch. Although ropes made from material having a high tensile strength are of

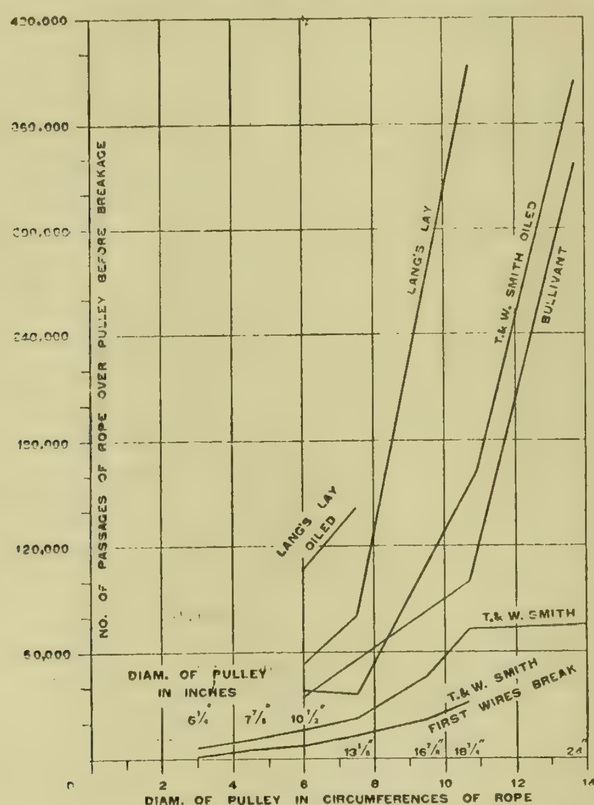


FIG. 1.—EXPERIMENTS ON DURABILITY OF WIRE ROPES AS AFFECTED BY DIAMETER OF PULLEY. (1890).

smaller diameter for a given load and a given factor of safety, yet this is not a great advantage to the crane designer because the stiffer character of the wires makes larger drums desirable, if the durability of the rope is to be considered, notwithstanding that some rope-makers claim as an advantage for the stronger material that it does enable smaller pulleys to be used with a consequent lower cost of the working parts of the crane.

The ratio of the diameter of the individual wires to the diameter of the completed rope is an important factor. If the wires are too large they are stressed considerably when passing over the pulleys, and accordingly the material is quickly fatigued and the wires break. Smaller wires, on the other hand, are more quickly worn through by rubbing against the pulleys and against their neighbours in the body of the rope. The stress in a wire due to bending round a pulley is directly proportional to the modulus of elasticity and to the diameter of the wire, and inversely proportional to the radius of the pulley; therefore the radius of the pulley should be increased with an increase in the modulus of elasticity, if the same number of bends is to be endured by a stronger wire of the same diameter. Unfortunately a theoretical calculation of the stresses induced in the wires of a rope by being bent over a pulley does not alone afford a reliable guide to the length of life to be expected from the rope, for consideration must also be given to the mutual wear that takes place amongst the wires.

Assuming for the purpose of comparison that two ropes are constructed of equal size, one from wires half the diameter of those in the other, then for equal strength the one rope will have four times the number of wires, and each of the wires will have one-quarter the cross sectional area. According to the usual formula, the stress due to bending will be half as severe in the smaller as in the larger wires, when the ropes are bent over pulleys of the same diameter. If it be allowed that a reasonable figure for the estimated stress due to bending an ordinary rope over a pulley of a size usually adopted in crane design be, say, 30 tons per square inch, and the stress due to the suspended load be 10 tons per square inch, there will be a range of stress of 40 tons per square inch in the material each time the maximum load is lifted and released, and the corresponding stresses in the rope of finer wires will be 15 tons per square inch due to bending, and as before 10 tons per square inch due to the suspended load, or a total range of 25 tons per square inch.

Judging by the discussion that took place on Messrs. Eden, Rose, and Cunningham's Paper before this Institution in November last, on "The Endurance of Metals," there is, as yet, no agreement as to the exact effect upon the endurance of variations in the working stresses. It seems, however, to be reasonable to assume that a reduction in range of stress from 40 tons per square inch to 25 tons per square inch would increase the life of material, such as ropes are composed of, about 500 times. As no such improvement in the life of a rope has ever been experienced, or is to be reasonably expected, it must be taken for granted that abrasion is the principal factor in limiting the life of wire ropes, and therefore the effect of abrasion upon the suggested rope of finer wires may now be considered.

When the rope of finer wires is passing over the pulley, there being four times as many wires in it, the pressure at each point of contact between the rope and the pulley, and between the individual wires of the rope may be assumed to be one-quarter of what it is in the rope of larger wires. The wires being of half the diameter the damage done to them by contact, even under this lower pressure, will be at least half as much as occurs to the coarser wires in the other rope, and this half damage done to a wire of one-quarter the sectional area will result in the cutting through of the wire in half the time, so that the effect of abrasion upon the rope of finer wires will be twice as great. If a smaller pulley be used for the rope of finer wires, as suggested by some authorities, the pressure at the points of contact and the stress due to bending will be proportionately increased, so that it may reasonably be expected that with a pulley-diameter bearing the same proportion to the diameter of the wires the life of the rope with fine wires will be one-quarter of that of the rope of coarser wires working over a pulley of correspondingly increased diameter.

A German investigator (Ernst Heckel) refers to the very great surface pressures on the wires at the place of contact with the pulley (amounting in his opinion to as much as 12 tons per square inch) as a vital point in connection with the wear of wire ropes. This high pressure, accompanied as must be the case by relative movement even if quite small, readilly accounts for the wear which takes place on the surface of the wires where they touch the pulleys or the other wires in the rope.

(*b*) **Diameter of Pulleys and Arrangement of Ropes.**—The lists issued by makers of wire ropes contain recommendations as to minimum sizes to be adopted, but no information is given as to the effect of using pulleys of different diameters. The author has felt for many years past the want of such information: the experience of users afforded no reliable guidance, presumably on account of the great difference in the conditions under which ropes work in different shops. Reference to a paper read before the Manchester Association of Engineers, by Mr. Matthews, in 1902, brings to light one great difference in the working of cranes. Mr. Matthews, in his

* Paper read at the Belfast meeting of the Institution of Mechanical Engineers, July, 1912.

paper, suggested that 400 to 1,700 lifts per crane per annum was the amount of duty required from certain cranes under his control, while the present author, in the discussion on Mr. Matthews' paper, mentioned 32,400 to 43,200 lifts per crane per annum as representing his own experience in another class of work. Other important features that will affect the life of a crane rope are the average weight lifted and the average height of lift; cranes are generally occupied with loads much below their nominal capacity, but this will vary in different workshops, as will the proportion between the maximum height of lift available and the height most frequently attained by the hook.

Enquiries addressed to the users of cranes elicited very various replies; ropes working upon cranes of the same general design were found to last for periods of from two years to ten years and upwards, one correspondent suggested that 20 years might be expected from ropes on cranes (of from 5 to 20 tons capacity) if damage from accidental causes could be eliminated. As might be expected, the ropes on foundry cranes have not so long a life as in erecting shops, the relative difference being perhaps as three is to five.

The most reliable and consistent information that the author has been able to discover (with the assistance of numerous friends and correspondents, and also of the library staffs of the Institution of Mechanical Engineers, in London, and of the Engineering Library, in New York, to all of whom his sincere thanks are due) is contained in a paper by Mr. A. S. Biggart, published in 1890. The experiments to which this paper refers were undertaken with the object of selecting the best form of rope to be employed in the construction of the Forth Bridge. A full description of the apparatus used and the details of the investigation will be found in the original paper, and the present author will content himself with a short reference to the experiments, and an abstract from the conclusions arrived at, adding some deductions he has made for his own guidance and for the purpose of this paper. The apparatus used by Mr. Biggart contained two pulleys, round which the rope under trial was passed, the lower pulley being weighted to give the required tension on the rope. The experiments consisted in passing the ropes, under a normal working load, to and fro over the pulleys until breaking ensued. Experiments were repeated with different diameters of pulleys and different makes of rope, and the accompanying diagram, Fig. 1, shows the life of different classes of rope as effected by the diameter of the pulleys.

The effect of oiling the ropes is shown by the diagram to be very beneficial, increasing the life of a given rope by two or three times. This is obviously due to the reduction of the cutting action of the wires upon each other. Experiments were also made to ascertain the effect on the life of a rope of running it over pulleys so arranged that the rope was subjected to reverse stresses, Fig. 4. The results obtained from this series of experiments showed that generally the life of a rope working under such conditions was only one-half as long as a similar rope bent in one direction only.

Fig. 1 is based upon the actual figures tabulated in Mr. Biggart's paper, while Fig. 2 shows the present author's approximations, as obtained by the simple method of drawing fair and regular curves through or near the points representing the results of Mr. Biggart's experiments over such a range of pulley diameters (measured in terms of the circumference of the ropes) as obtain in general overhead crane practice. Several interesting deductions may be drawn from a study of these figures. The time of breakage of the first wires of a rope in the lowest curve is only recorded for one make of rope, but comparing it with the second curve, which shows the time of breakage of whole ropes of the same make, it will be seen that when the first wire breaks the rope may be assumed to have passed through one-half of its life and as no one knowingly works a rope until it breaks entirely, then the breakage of even a few wires is a sign that a rope should be carefully watched, and replaced by a new one at an early opportunity.

The effect of varying the proportions of diameter of pulley to diameter of rope is one of the most important features to be noticed. Speaking generally, Mr. Biggart's experiments show that increasing the diameter of the pulleys by an amount equal to two circumferences of the rope will double the life of the rope. This is approximately correct for all the varieties of rope and conditions experimented with, and may therefore be taken as equally correct for all the varying conditions under which cranes are worked. It is very remarkable that so simple a rule should evolve from such numerous and varied experiments, and the author hopes that its statement in this form will be of some value to designers and other interested members. That it is sufficiently correct for all practical purposes may be readily seen by referring to Fig. 3, where the ratios of pulley diameters to ropes are plotted as abscissæ to a linear scale, while the durability of the ropes is represented by ordinates drawn to a logarithmic scale.

These conclusions enable one to express a definite value for the effect upon the durability of ropes, of the various arrangements of pulleys that are commonly adopted in overhead cranes, some of which are illustrated in Figs. 5 to 11. Assuming that Fig. 6 (in which the ropes make three bends in working, namely, one at the upper drum and one on each side of the lower pulley, *i.e.*, at entering and leaving) is the arrangement most frequently adopted in practice, and representing the anticipated life of the rope under these conditions by 100, then the relative lives of the ropes in each of the other arrangements indicated will be shown in Table I.

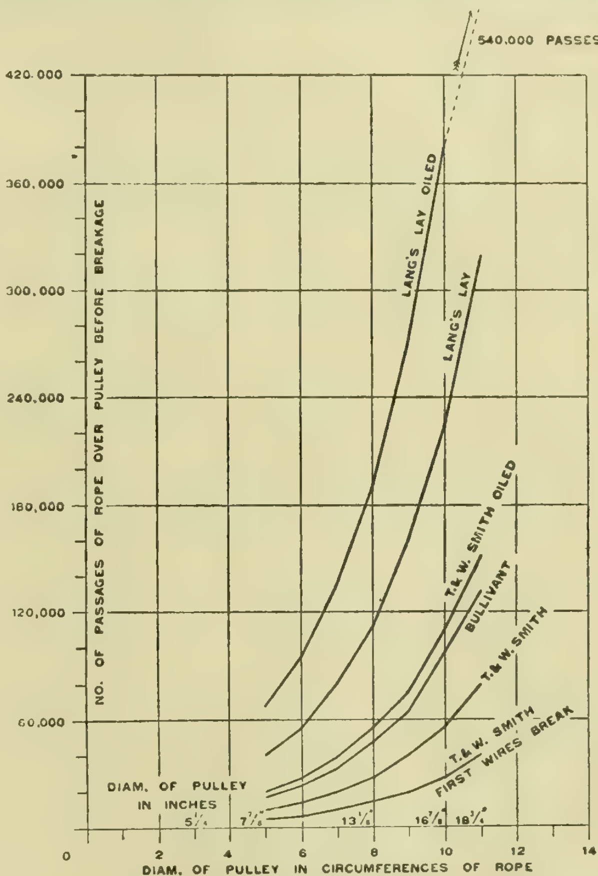


FIG. 2.—REGULAR CURVES BASED ON DATA IN FIG. 1.

TABLE I.—*Comparison of Anticipated Length of Ropes arranged as shown in Figs. 5 to 11.*

Fig. No.	Number of Bends.	Relative Life of Rope.
5	1	300
6	3	100
7	3*	75
8	7	43
9	11	27
10	7*	37½
11	11*	25

* Including one reverse bend which is twice as effective in wearing out the rope.

If it be desired to design each of the above arrangements of pulleys so that the ropes shall have equal durability, then the ratio of the drum diameters to rope circumference (if the law indicated by Figs. 2 and 3 is to be relied upon) must be increased as shown in Table II.

It is quite usual for purchasers to specify in their enquiries that the diameters of the pulleys and drums must bear a certain relation to the diameter of the rope, but the author wishes now to emphasize the point that this stipulation is not sufficient in itself without some consideration being also given to the arrangement of the rope and pulleys.

Table II.—*Required Increase in Diameters of Rope Drums (measured in terms of Circumference of Rope) required to give Equal Durability.*

Fig. No.	Increase over Diameter called for by Fig. 6.
7	1 circumference of rope.
8	$2\frac{1}{2}$ circumferences of rope.
9	4 ,, ,,
10	3 ,, ,,
11	4 ,, ,,

If the generally accepted ratio of seven circumferences, or twenty-two diameters, of the rope for the diameter of the barrel be assumed as suitable for the drum and pulleys arranged as in Fig. 6, then the diameters for the other figures, to give equal durability, should be as shown in Table III.

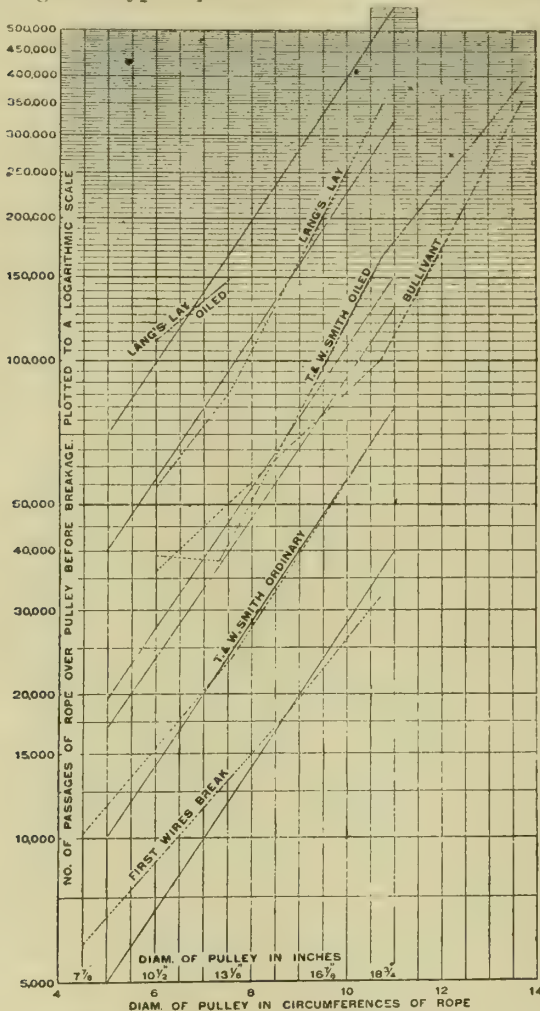


Fig. 3.—Durability as affected by Diameters of Rope and Pulley.

Table III.—*Ratio of Diameter of Pulleys and Drums to Circumference of Rope to give Equal Durability.*

Fig. No.	Ratio of Pulley and Drum Diameter to Rope Circumference.
5	4 to 1
6	7 to 1
7	8 to 1
8	9·5 to 1
9	11 to 1
10	10 to 1
11	11 to 1

To make the comparisons quite fair between the different arrangements it must now be pointed out that owing to the increased number of falls of rope adopted in Figs. 8 and 9 the size of the rope may be reduced as shown in Table IV. while retaining the same factor of safety.

Table IV.—*Relative Rope Circumference allowing for Smaller Ropes due to increased Number of Falls.*

Fig. No.	Number of Falls.	Relative Rope Circumference.
5	2	140
6	4	100
7	4	100
8	8	70
9	12	57
10	8	70
11	12	57

Combining the figures given in Tables III. and IV. will give drum and pulley diameters as shown in Table V.

Table V.—*Drum and Pulley Diameters resulting from a combination of Tables* III. *and* IV., *and still assuming that* 100 *represents the Condition in Fig.* 6.

Fig. No.	Ratio of Pulley and Drum Diameter to Rope Circumference according to Table III.	Relative Circumference of Rope as per Table IV.	Resultant Pulley and Drum Diameter assuming Fig. 6=100.
5	4	140	80
6	7	100	100
7	8	100	114
8	$9\frac{1}{2}$	70	95
9	11	57	90
10	10	70	100
11	11	57	90

The noticeable feature in the last table is that whether two, four, or six falls are adopted the diameter of the drum and pulleys should remain about the same, if the ropes are to have equal durability (compare Figs. 8 and 9 with Fig. 6). A recent text-book upon the subject of crane design states (as an advantage of a large number of falls of rope) that the proportionately larger pulleys and barrel will ensure long life for the ropes, but the author hopes that he has made it clear that very large proportions are necessary to ensure a reasonable life for ropes on cranes with many falls of rope. Reference to Fig. No. 7 and Fig. No. 10 in Table V. shows the increase that should be made in the diameter of the drum and pulleys if a reverse bend occurs in the run of the rope.

Another important detail in crane design may now be referred to. In Fig. 6, as already mentioned, the ropes make two bends at the lower pulleys to one at the drum, and therefore, if the lower pulleys are made of the same diameter as the drum, they will be responsible for two-thirds of the wear and tear of the rope. Now it is usually difficult to increase the diameter of the working barrel or drum of a crane because to do so affects the ratio of the gearing, and also requires a much larger framework with a correspondingly greatly increased cost of manufacture, but if it is agreed, as a result of Mr. Biggart's experiments, that increasing the diameter of the pulley, over which a loaded rope passes, by an amount equal to twice the circumference of the rope reduces the evil effects of bending the rope round it to one-half, then a simple means of improving the durability of crane ropes is immediately at the disposal of the designer, namely, to increase the diameter of the pulleys in the blocks, leaving the drums of the original size, as indicated by Fig. 12. This alteration can usually be effected without serious alteration of the design, and may even be carried out on existing cranes.

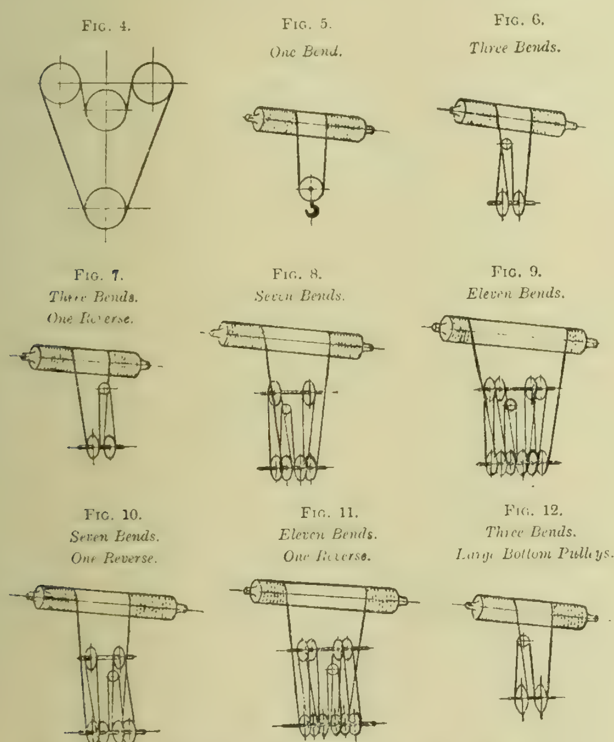
The result of increasing the diameter of the pulleys (as shown by Fig. 12) by an amount equal to two circumferences of the rope, will be that the effect of the double bend round the lower pulley is halved, and the result effect of the three bends will be equal to two only, and the relative life of the rope will be increased by 50 per cent., or the drum diameter might be reduced by an amount equal to 1·2 times the circumference of the rope with a corresponding reduction in the

size of the framework of the crab or winch, while still retaining a relative life for the rope equal to Fig. 6. In this case the diameter of the lower pulleys would only require to be about one circumference of the rope larger than the original size of Fig. 6.

In making the foregoing comparisons of diameters of drum and pulleys with different arrangements of rope it has been assumed that the hook is raised to the full height available at each lift. This, however, is not the case in actual practice, the majority of loads not being raised one-half this height.

This consideration brings to light another great advantage of Fig. 12 as compared with any of the others. Where, as is usually the case, the average height of lift in a shop does not reach half the maximum available, then that portion of the rope which passes under the lower pulley does not reach the upper drum, and accordingly is only subject to the wearing action of the two bends at the lower pulley. If therefore the effect of the bends at the lower pulley is reduced to one-half, by the proposed increase in diameter of the pulley, then the actual life of the rope will be doubled, instead of only being increased by 50 per cent. as was first assumed.

Where there are more than two falls of rope, as in Figs. 8 and 9, the effect of increasing the diameter of the pulleys by an amount equal to two circumferences of the rope is also very marked, reducing the effect of the seven bends in Fig. 8 to



VARIOUS ARRANGEMENTS IN LIFTING APPLIANCES. (See Table I.)

four and a half, with corresponding increase in the lift of the ropes. This shows up the fault of those designers who adopt large drums (in order to obtain the great length of rope entailed by high lifts) and are yet content to make the pulleys of small sizes, when they could enormously increase the durability of the rope by the adoption of larger pulleys at little extra cost.

When the rope makes a reverse bend at the barrel, as in Figs.7, 10, and 11, the barrel ought to be increased in diameter to counteract the effect of the reverse bend. Thus, if in each of these cases the diameter of the drums were made larger by an amount equal to two circumferences of the rope, the durability of the rope would be equal to Figs. 6, 8, and 10 respectively.

Some continental makers point out, very rightly, the desirability of making the compensating pulleys of reasonable size. The motion over such pulleys is apparently considered as negligible by some designers (judging by the forms of construction adopted), but this point of view overlooks the movement of the rope due to the swinging of the load, and the repeated bending of the rope at the same place over a small radius has an appreciable effect upon the durability of the rope.

Although the deductions laid down here appear too simple to need elaboration, a glance at the designs of many modern cranes shows that neither the designers, nor the purchasers, are aware of the importance of the principles involved, otherwise we should not see modern cranes in this country with reverse bends in the ropes, and as many as eight plies of rope to carry the load on cranes of only 15 tons capacity, while at the recent Brussels Exhibition there were cranes exhibited by well-known continental makers showing the same faults.

The author would like to add that while he is aware of many conditions affecting the durability of ropes other than those he has referred to, he regrets that want of first-hand experience prevents him from dealing with them as he would like, and he hopes that other members will help to make up the deficiency.

The qualities of wire used vary considerably, and this, together with the heat treatment in manufacture and the care taken by the makers in testing and examination, are questions that makers of ropes are in a better position to discuss than users.

The "lay" of the strands and the lubrication of the rope when in use have each a considerable effect upon durability, and some guidance on these points may be obtained from Fig. 3, where "Lang's lay" is shown to have more than double the life of ropes of ordinary "lay," and ropes that are oiled last more than twice as long as when this precaution is neglected, as already mentioned. The superiority shown by "Lang's lay" naturally gives rise to the question as to why it is not exclusively used, and the answer the author has obtained from rope-makers is that such ropes must be very carefully handled to avoid "kinks," and also they are found to be more liable to "spin."

NEW COAL DUST EXPERIMENTS.

THE EXPERIMENTAL PLANT AT ESKMEALS.

THE first report on Explosions in Mines by a Departmental Committee of the Home Office describes the experimental work which has been already done at Altofts Colliery, Normanton, the effect of which it says was "to demonstrate conclusively the fact that coal dust in the complete absence of fire damp or other inflammable gas is explosive when raised as a cloud in the air and ignited under conditions which may exist in a coal mine, and, moreover, is capable of producing such destruction as is observed after a colliery disaster. In the second place, the experiments indicated that the admixture of increasing proportions of an incombustible dust with the coal dust rendered the initiation of an explosion increasingly difficult to accomplish, and that therefore a means of preventing coal dust explosions in mines might possibly exist in the treatment of the roads with incombustible dust, such as stone dust. In the third place, experiments on the mode of propagation of coal dust explosions gave an indication of the manner of their development during the initial stages, and suggested a way for a more complete study of the problem." Not only in this country, but also on the Continent and in the United States Government departments, and mineowners had recognised the importance and magnitude of the problem, and had instituted large-scale experiments on the propagation of explosions in coal mines. On being approached by the Mining Association the Royal Commission on Mines communicated a proposal to the Government, which ultimately undertook to provide the necessary funds for experiments, and a Consultation Committee was formed, the first meeting being held at the Home Office in May of last year. The site at Altofts being no longer available, after examination of numerous sites a piece of land on the seashore was chosen near Eskmeals, in the county of Cumberland, for the carrying out of experiments.

The chief features of the apparatus consist of three steel tubes or galleries, in which explosions with coal dust and gas can be brought about and tests made on the effect of stone dust in stopping them. The largest gallery, 7ft. 6in. in diameter and about 800ft. long, is made of disused boilers, and is the one that was employed at Altofts. It has been

placed east and west with one end pointing seawards, and there is room for its length to be increased to 700 yards in a straight line if that course should be found desirable in the future. It rests on sleepers laid on the shingle, and care has been taken to make the joints between the different boiler sections gas-tight by means of asbestos rope. At its eastern end there is an arm turning at right angles, and from this again a second arm parallel to the main tube leads to the fan-house, which contains a Sirocco fan, also from Altofts, driven by belt from a Robey semi-portable engine capable of developing 25 h.p. A smaller gallery, 400ft. long, made of 3ft. flue pipes and supported on concrete pillars, runs alongside the main gallery, and can be joined to it at each end by curved tubes. Arrangements have been made for inserting various diaphragms and constrictions in its course, and it can be divided up into compartments for containing gas mixtures, so that, for example, a gas explosion started in it can be used to initiate a coal dust explosion in the larger gallery. The firing station in connection with these two tubes stands on a sand hill just to the north of them, and consists of two boiler shells of ½in. plate, placed end to end and of a total length of 60ft. From this station also are controlled the recording instruments, which are mounted in a series of huts between the two galleries. Records will be taken of pressure and velocity, and there is in each hut an apparatus which will photograph the explosion, through a slit in the tube covered with thick glass, on a sensitised disc which will be rotated at a speed quicker than that of the travel of the explosion, and will thus yield a magnified image. Nearer the sea there will be an observation station commanding a view of the mouth of the tube. A gas-holder is being constructed between the larger and smaller galleries to supply gas for the experiments.

Still further to the north there is a third tube, 1ft. in diameter and 150ft. long, in connection with which there is an electrically-driven Sirocco fan, together with a gas-holder having a capacity of 1,500 cub. ft. This fan is controlled from the so-called "chronograph house," which will be used for the adjustment and measurement of the recording instruments, and which will contain a large dark-room for the development of the photographic records. It is expected that this small tube will be found very useful for experiments preliminary to those to be tried in the larger tubes, and, doubtless, in many cases these experiments will be sufficient to settle the point at issue without recourse to the main tube at all.

South of the main tube are built a number of houses containing accessory plant. In the power-house there are two semi-portable Robey steam engines of 25 h.p. each, which drive two dynamos, generating current one at 100 volts and the other at 200 volts, and adjoining it is an accumulator room filled with 60 chloride cells. Another house contains the coal-crushing plant, which is able to furnish dust of three different degrees of fineness; the crusher itself is the one which was used at Altofts, and it is driven by a 10 h.p. semi-portable engine. The gas-making plant consists of two horizontal retorts, with two lime purifiers, which deliver into two gas-holders, one having a capacity of 4,000 cub. ft. and the other of 1,000 cub. ft. The smaller gas-holder is intended to catch the earlier products of distillation, which resemble pit gas in containing little or no hydrogen, and it can also be used for the storage of other gases or vapours with which it may be desired to experiment, *e.g.*, petrol. This gas-making plant is, of course, connected by mains to the two other gas-holders which serve the two larger galleries and the small tube respectively. Close to the retort-house there is a carpenter's shop and mess-room for the staff, which number a dozen, most of them mechanics skilled in different branches, and a building, containing a committee room, secretary's room and offices, caretaker's room, kitchen, and some living rooms, stands near by. Most of these buildings are substantially constructed of brick plastered with Portland cement, which is rendered waterproof by a special process, and their roofs are either of slate or of iron placed on boards covered with felt. They are chiefly grouped together towards the firing end of the main gallery, which is not the point where bursting is likely to occur, but for their protection strong barriers consisting of two rows of sleepers with a couple of feet of sand between them will be erected where they seem desirable.

Mention may also be made of a lamp-testing station, though the work to be carried on in it is not on behalf of the Coal-Dust Explosions Committee. It stands close to the small tube, and it will be devoted to tests designed to ascertain the behaviour of different types of miners' safety lamps in currents of explosive gas, their light-giving power, and their resistance to injury such as might be caused if they were dropped by the miner.

A light railway of 20in. gauge connects the experimental station proper with the laboratory, which stands about 350 yards to the eastwards on the other side of the sand-hills. It consists of four large rooms, and adjoining it is a house, occupied by the chief chemist, Mr. Wheeler, the provision of which was rendered possible through the action of the Mining Association, who, on learning that no part of the money placed at the committee's disposal was available for housing, presented a sum of £1,500 to be used for that purpose. One of the rooms in the laboratory is used as a store, another is fitted up with a lathe, drilling machine, and other tools, by the aid of which repairs can be effected to the instruments; while the other two are equipped with a complete set of apparatus for physical and chemical experiments, particularly in connection with gas analysis and the phenomena of explosions. Water, gas, and electricity are laid on, the first coming from the village of Bootle, a few miles off, and the two latter from the experimental station. The electricity supply is available in two voltages, 100 and 200, the latter being intended for power purposes, though an oil-engine is installed to work the machine tools. The laboratory and other buildings are in communication by telephone.

From the foregoing description it will be seen, says the report, that provision has been made for complete investigations into the initiation and spread of coal-dust explosions, whereby we hope to ascertain the means of preventing or limiting them. It may therefore be some time before we are able from our own experiments to recommend definite precautions. There is, however, one point to which it is desirable to draw attention—the proposal to use an inert dust as a preventative. It is difficult to state the exact date of the idea of using stone dust as a protection against coal-dust explosions, and we do not pretend to give the complete history of the progress of thought upon the question. We may, however, mention a few instances in which it was brought prominently into notice. That an inert dust might prevent the ignition of coal dust seems to have been suggested by the facts observed in several mine explosions, such as that at Seaham in 1880. In our opinion further experiments upon the action of stone dust are essential before any final recommendation can be made.

Attention is called to steps taken at various collieries to put the theory into practice, and the committee express the opinion that, even in the present incomplete state of their knowledge as to the exact action of inert dust, those who are working and carrying coal along dry and dusty roads would be well advised to take into consideration this means of obviating danger. The committee add: "We do not, of course, question the utility of watering and of keeping the mine clear of dust or of safety cartridges, tamping, and the various other remedies which it will be our duty to examine. Moreover, the proposal to prevent the ignition of coal dust by admixture with an inert dust may not be applicable in all mines, but we consider that the results of the experiments, so far as they have gone, are sufficiently striking to merit serious attention."

The effect of dust upon health is also dealt with. The results of sundry experiments went to show that dust if of slate or shale or other argillaceous substances was not dangerous. On the other hand all kinds of dust containing finely powdered silica in its crystalline condition, such as was found in Sheffield grinders' shops, were apt to produce fibrosis of the lung, and thereby to facilitate the production of tuberculosis. It followed therefore that such dusts were likely to be dangerous.

RECENT DEVELOPMENT OF THE AMERICAN LOCOMOTIVE.*

BY GEORGE R. HENDERSON.

SIZE AND POWER.

TEN or twelve years ago the steam locomotive had assumed such proportions that it was thought by many engineers that the limits of size and capacity had been practically reached. The increase in weight had been going on steadily for years, but with comparatively few advances that, at a single bound, were remarkably in excess of what had previously been done. About this time, however, a number of circumstances occurred which made it absolutely imperative that more powerful locomotives be obtained, and these last ten years have produced different reasons for increasing the power of the locomotive, treading fast one upon the other.

The advent of large-capacity freight cars has resulted in a train that could be more easily handled with a large tonnage than it could be in the old cars of less capacity, as the train length is shorter and the number of cars in the train considerably diminished for a given tonnage, which is a very important factor in connection with the proper operation of the brakes when descending grades. Instead of cars of 30 tons capacity, which were the common maximum a decade since, 50-ton cars are now very plentiful, and even cars of 75 or 80 tons carrying capacity are being seriously considered. This means that for a train of the same number of cars double the tonnage can be hauled and a more powerful locomotive can be economically used.

The introduction of steel passenger equipment, with a view to eliminating many of the horrors of fire and collision, also calls for more powerful locomotives, as the weight of these cars has been very considerably increased. In olden times a 60-ton car was considered a very heavy vehicle, but nowadays 75 tons is not at all abnormal, and a weight of 90 tons has been reached.

The agitation for increase in wages of all men connected with the transportation department of railroads has been more or less generally successful, and in order to offset, to some extent, these increased expenditures, reduction in operating expense has been necessary. This is brought about very largely by the increased capacity of the locomotive. As an example of what can be done in this line, some years ago a road with which the writer was connected found, by the purchase of some passenger locomotives of considerably greater power than heretofore used, that each of these engines in the first year during which they were operated saved $5,000 in reducing the expense incidental to double-heading trains and running two sections, where the necessary cars could be handled by one of the new engines.

The increase in traffic due to the natural increase in population, which has for the United States amounted to 20 per cent. in the last ten years, has in many cases called for either double-tracking, large additions for side tracks, or other provisions for handling an increased movement of tonnage over and above what could be arranged with the old facilities. With an increase in the power of the engine it is possible not only to handle tonnage more cheaply, but to handle a larger amount without any additional efforts in the way of dispatching or interference with other trains; for instance, if we could double the train load, we could practically move twice the amount of tonnage without increasing the number of meet orders or delaying trains in the opposite direction. On this account alone the large locomotive has been invaluable in enabling the companies to increase very greatly their tonnage without having to make large expenditures for improvement in tracking facilities, greater number of sidings, extra track, &c., and this has been no small part of the burden removed, although we do not hear as much said about this part of the operating problem as some of the others which we have mentioned.

The more recent decision of the Interstate Commerce Commission that the railroads should economise instead of increasing their rates calls for an additional effort in this line, and these cumulative experiences, coming closely one upon the other, within the past decade have brought about a locomotive of size and power which was not even dreamed of ten years ago.

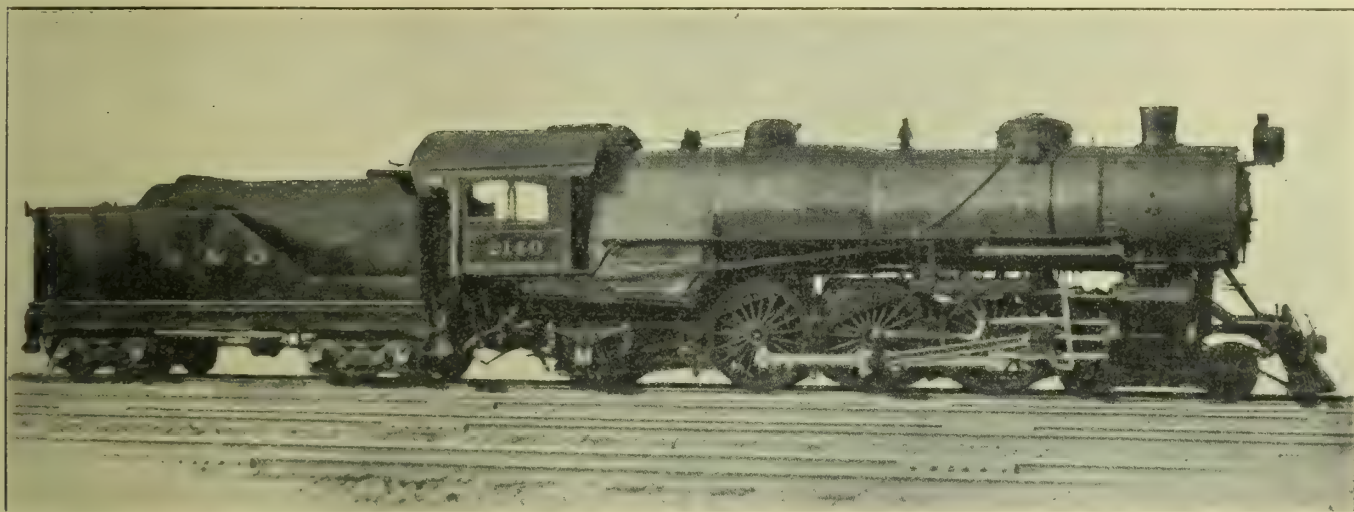


FIG. 1.—PACIFIC TYPE LOCOMOTIVE.

The electric locomotive has made its appearance, and has done very good work in certain localities, and in order to compete with such an engine, which has the output of a large stationary power-house behind it, the steam locomotive has had to increase its capacity for exerting power. For years the clearance or height and width possible for locomotives, owing to the outlines of tunnels, heights of bridges, proximity of station platforms, buildings, &c., has prevented any considerable increase in these two directions, so that the remaining dimension, viz., that of length, was the one direction in which increases could be made. This has brought about, naturally, engines of long wheel base with long boilers, and, while a few years ago tubes of 16ft. length were considered as quite long enough for good design, we now find them extended to as much as 25ft., and the end is probably not yet. Of course, these increases in size mean increase in weight, which, while it is a natural consequence of the increase in power, is also necessary to provide sufficient adhesion to make use of this increase in power. This, however, means necessity for heavier track and bridges, and, in order to reduce the load on track and bridges as much as possible, the extension of this weight into increased length has helped to keep down the weight per lineal foot. This, however, is increasing, as, while a few years ago 25 tons was thought to be a very large weight on one pair of drivers, 30 tons is now very frequently considered, and is, in fact, already exceeded in a few cases.

The question of longer boilers and longer engines leads us to a good many complications which have heretofore been avoided. While boiler flues have been used up to 25ft. in length, this is about the limit at which the mills are able to roll them, and besides, it is considered wise not to increase the

* Paper presented at a meeting of the Franklin Institute, April 17th, 1912.

lengths too greatly without having experience of gradual extensions. The new lengths of locomotives in many cases require, for structural reasons, if nothing else, a barrel as great as 53ft., and, in order to fill up this space, there have been various means adopted to supplement the length of the flues. Combustion chambers extending from the firebox forward, a distance of 5ft. or 6ft., have been introduced, and the amount of boiler has been utilised for feed-water heaters, reheaters, superheaters, and other devices, all of which tend toward economical operation and make good use of the extra length of boiler shell. These different devices will be referred to more in detail later on, but the reasons for their existence and for having space to apply them, which we did not have some years ago, should be considered at the present time.

The lengthening of the boiler and the engine means that flexible wheel bases must be introduced. The favourite type of long, rigid wheel base engine has generally been the consolidation, consisting of one pair of truck wheels and four pairs of driving wheels; to this, later on, a trailing truck was added giving us the 2—8—2, or Mikado, type of engine. There were several reasons for the introduction of this type; probably the first one was to provide an engine which could be backed around curves and switches as easily as run forward. Consolidation engines have been in the past very largely used as helper locomotives, and, after helping a train up a mountain for ten or twenty miles, it was often desirable to back them down hill to be ready for the next ascent. If the road was crooked, derailments were likely to occur when having only a driving wheel to negotiate curves. The trailing truck, therefore, was originally introduced to enable these engines to operate with equal satisfaction around sharp curves in either a forward or backward direction. The construction of boiler was kept very similar to the Consolidation engine; that is, the firebox was above the rear drivers and the rear truck was purely for guiding purposes.

With the desire for additional heating surface requisite for maintaining higher speeds, it was found that advantage could be taken of the trailing truck to bring the firebox entirely back of the drivers, and thereby make it deeper, as the truck wheel was so much lower than the drivers. This gave longer tubes and a better firebox for the proper combustion of fuel, and the increase in firebox volume and heating surface has been considered so essential that nowadays the Mikado engine is used for road service, principally on account of the large boiler capacity which can be obtained thereby.

In the same way that the Consolidation locomotive was developed into the Mikado type, the Pacific locomotive was the outcome of the ten-wheel engine. In the olden times the ten-wheel engine was built with a deep firebox between the frames and between the middle and rear driving axles, but, with the increase in dimensions necessary for modern locomotives, this space was too much restricted, and the firebox was raised entirely above the rear drivers. For the low wheels in freight service this answered well enough, but when it came to passenger engines with wheels from 70in. to 80in. diam. the boiler was raised very high, and there was little depth of firebox possible. The addition of the trailing truck to this type of engine, therefore, allowed a deep fire box, and also a wide one by extending the boiler backwards until the firebox was entirely in the rear of the driving wheels. This is illustrated by Fig. 1.

The Pacific type of locomotive may also be, in a measure, considered the logical development of the Atlantic type of engine, which first made its appearance about 15 years ago. The original engine of this wheel arrangement was constructed for the Atlantic Coast Line in 1895, and was simply a ten-wheel engine with the rear driver changed to a trailing wheel in order to give room for a deep and longer firebox, which could not be obtained with the regular high driving axle at the rear. The particular object to be obtained in this case was an increase in steaming power to haul at greater speed heavy trains which were needed for carrying the passenger traffic at that time. This engine, it will be noted, was not provided with a trailing truck, but the trailing wheels were simply placed in pedestals, and located at about the same place where the third pair of drivers would have been in a ten-wheel type of locomotive. In this case it was not a question of adhesion so much as the possibilities of sustained horse-power at high speeds, and, as the tractive force of a locomotive always diminishes as the speed increases, the maximum adhesion is never used, except in starting and at very slow speeds.

The Pacific type of locomotive has become particularly popular for high-speed freight and heavy passenger service, and might now almost be considered the standard type of passenger locomotive used in this country for heavy trains at high speeds. For steep grades the Mikado type of engine has been used very successfully in passenger service, particularly on the Union Pacific Railroad, by making the driving wheels sufficiently large for the purpose intended and keeping the firebox over the rear truck, as shown by Fig. 2.

It has been a general axiom in locomotive construction that the diameter of the driving wheels in inches should be as great as the maximum speed in miles per hour at which the engine is intended to run, this resulting in a speed rotation

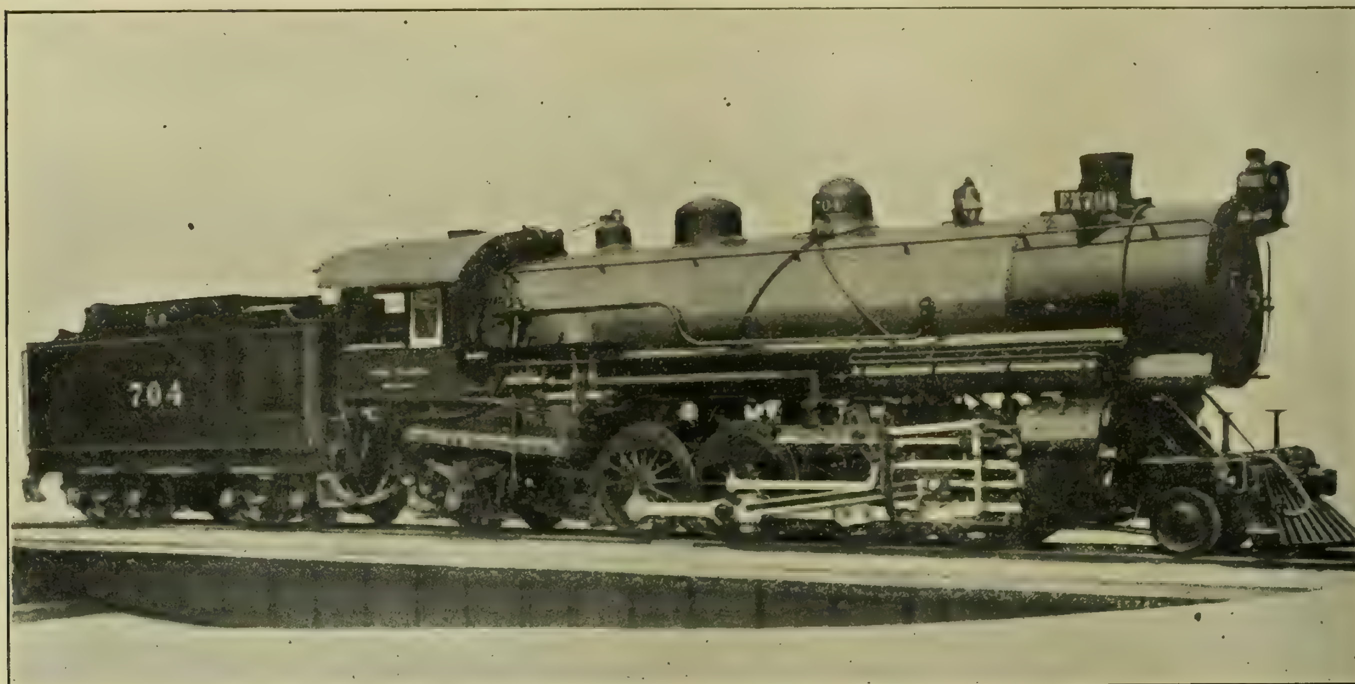


Fig. 2.—Mikado Type Locomotive.

of 336 revs. per minute when the speed above mentioned is attained.

In 1903 the Santa Fé type of engine, which is a 2—10—2 locomotive, was introduced, and which was really a Mikado engine with an extra pair of drivers inserted in the rigid wheel base. While it is the practice in this country to use flanged tyres on all the drivers of Consolidation locomotives and those having a less number of driving wheels, yet when it came to the five pairs of drivers the flange was omitted from the middle wheel. It had been the custom to use bald tyres on Consolidation locomotives, but experience later demonstrated that by placing the tyres of the front and back wheels closer together than the middle wheels the tyre wear was more uniformly distributed over the different wheels, and there was no difficulty in passing curves of fairly sharp radius. At the present time a locomotive of the 2—10—2 type with 30in. by 32in. cylinders is being built, reviving the Santa Fé type of nine years ago. These latter engines will be used on the Chicago, Burlington, and Quincy Railroad.

It seems, however, as if this was the greatest aggregation of driving wheels that could be used in a rigid wheel base, and when it is desired to use more than ten driving wheels it is necessary to go into the Articulated type of locomotive. The particular style most used in this country at the present time is termed the "Mallet," as it was originally proposed by M. A. Mallet, of Paris. In this device there are four cylinders, each pair operating a set of driving wheels in individual frames, the two sets being connected together by a hinged joint. This enables an engine with six, eight, or even ten pairs of driving wheels to pass curves with no more resistance than engines heretofore employed.

There have been two ways of connecting the boiler to such engines and frames, the original method being to have the boiler with a rigid shell firmly attached to the rear engine and to allow the front, or low-pressure section, to oscillate and slide transversely under the front end of the boiler, connection being made by means of flexible steam pipes (see Fig. 3). Sometimes, however, the overhang of the boiler is too great on sharp curves, and then recourse is had to the flexible boiler, or one with the "accordion" joint, as it is called. In this case both sections of the boiler are secured rigidly to their respective frames, but the accordion joint allows the boiler to bend when passing curves. This is illustrated by Figs. 4 and 5, the latter showing an enlarged view of the joint in the boiler.

In both these types of Mallet locomotives the rear wheels are operated by high-pressure cylinders receiving steam direct from the boiler, and this steam, after passing the high-pressure cylinders, goes through an intermediate receiver into the low-pressure cylinders, and finally to the exhaust. The various heaters of which we have above spoken are utilised in some cases, first, to superheat the steam before passing to the high-pressure cylinders, and, secondly, to reheat the steam in its passage from the high to the low pressure cylinders. The feed-water heater at the front end has been used to abstract heat from the gases during their last passage in the boiler, so as to increase the temperature of the water and bring it practically up to a boiling point (at boiler pressure) before being delivered into the boiler proper. These various combinations of heaters and compound cylinders, of course, very considerably reduce the fuel consumption, which is an extremely important factor, now that the boilers have assumed such enormous size. It has been found by experience that an ordinary fireman cannot, as a regular performance, put in the firebox more than from 5,000lbs. to 6,000lbs. of coal an hour, and, while for a short period some good men can exceed this rate, yet, ordinarily, it is unwise to expect him to handle more than this amount of fuel. The compound principle generally effects an economy of about 20 per cent., and as superheaters, reheaters, feed-water heaters, &c., may give as much more, it is plain that these devices have enabled us to get more power out of a locomotive fired by a single fireman than would be possible with ordinary simple expansion engines without the devices referred to.

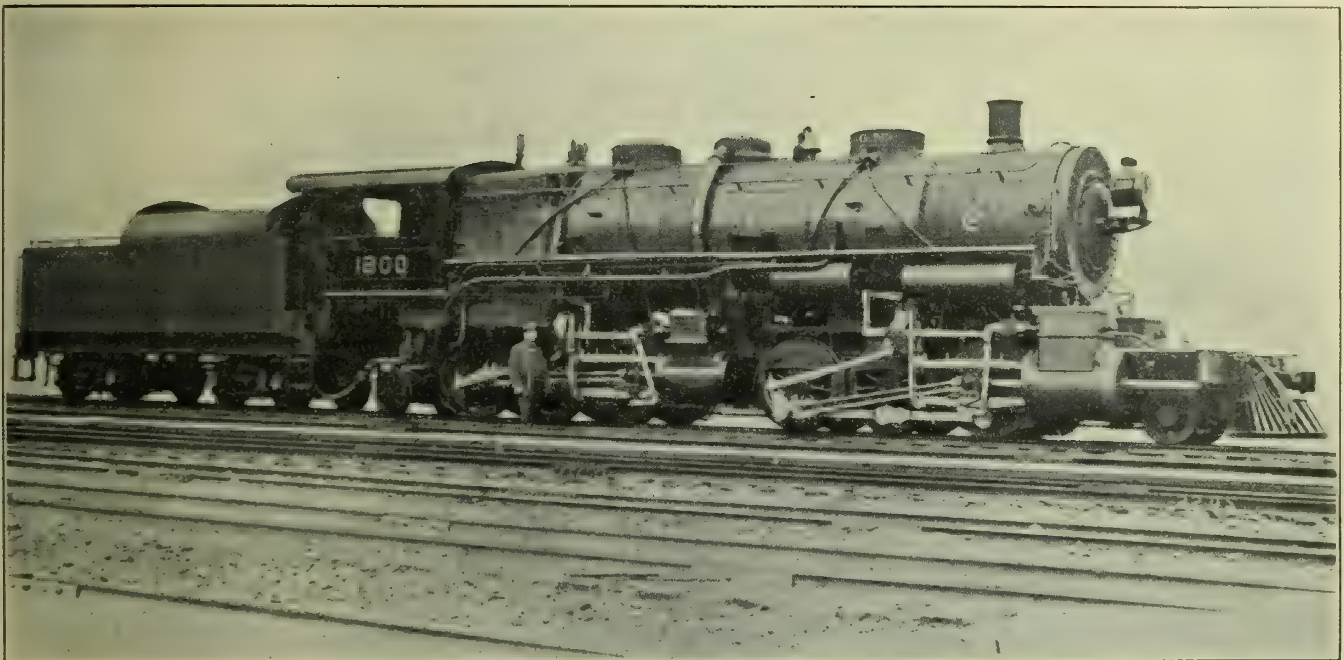


Fig. 3.—Mallet Locomotive.

The limit of physical endurance of the fireman has recently been recognised as the actual limiting factor in the development of power by a large locomotive, as it is found that locomotives with increasing size do not develop ordinarily horse-power in proportion to that size. Repeated tests of locomotives on testing plants and also in actual service indicate that 1 h.p. can ordinarily be obtained by from 2 sq. ft. or 3 sq. ft. of heating surface, the former value being susceptible of attainment with compound locomotives and those equipped with a special economical device, while the latter figure applies to the ordinary saturated locomotive without the devices above mentioned. Under ordinary conditions the saturated steam locomotive will develop a horse-power with about 4lbs. to 5lbs. of coal per hour, and for 1,000 h.p. there would be very nearly as much coal required as could be placed by an ordinary fireman. With compound engines, superheaters, &c., of course, the capacity of the fireman in horse-power can be very considerably increased, as above noted, but it is a fact that even locomotives with 5,000 sq. ft. or 6,000 sq. ft. of heating surface often deliver only about 1,200 h.p. or 1,500 h.p. This limitation of the steaming capacity, due to the human element of the fireman, has brought about the investigation and introduction of mechanical stokers, of which more will be said anon, but it is here mentioned in order to account for the

extreme sizes of locomotives that have been proposed, as well as some actually under construction. Of course, the same limitations do not apply to locomotives which burn oil, as there is no difficulty in getting sufficient oil in the firebox for practically any reasonable rate of combustion, and some of the largest engines heretofore built have been arranged to burn liquid fuel. This is notably true of the south-western part of this country, where the oil fields in Texas and California furnish a fuel that, in addition to overcoming the limits of physical endurance of the fireman, also enables steam to be generated at a cost considerably below that for coal. This is illustrated by the Southern Pacific locomotive in Fig. 6.

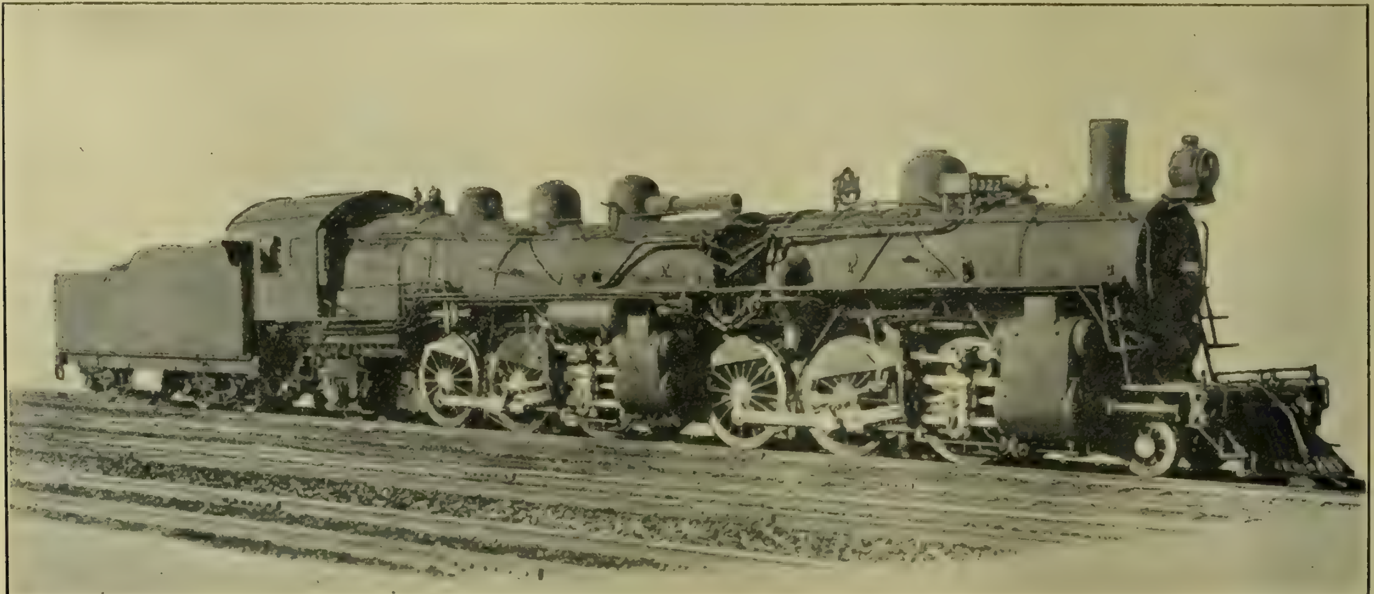


FIG. 1.—FLEXIBLE BOILER, MALLET LOCOMOTIVE.

Following these lines of increase, locomotives of more than two sections have been proposed in some cases in which the successive engines have received the steam in sequence, so as to form in effect a triple-expansion engine, and in other cases in which the steam has an expansive ratio of 2 obtained by exhausting from one pair of cylinders into two others. In order to keep down the length of the engine within reasonable limits, the tender can be made to do its share of the work, and, without increasing the length, and only slightly the weight and expense, a locomotive can be constructed having about 50 per cent. more hauling capacity than a heavy Mallet type of locomotive as now in use.

The Mallet locomotive is no experiment, as many hundreds of them are in use in this country, but the triplex Mallets are still a problem for speculation and production. The first compound locomotive built by the Baldwin Locomotive Works was constructed in 1889, and, while the compound type of locomotive for a few years after this was very strenuously sought on account of its fuel economy, it was found that there were other objections which, in many cases, overcame the benefits of reduced fuel consumption. With the introduction of the Mallet locomotive, however, the compound feature is of great importance, first, as it reduces the amount of fuel needed to produce a given amount of power, thereby enabling a large locomotive to be successfully handled by an ordinary fireman, and, secondly, that the pressure of steam passing through the flexible joints is only about one-third of the boiler pressure, thereby reducing the difficulty of keeping these joints tight. When this type of engine was first placed in service it was feared that these ball joints would cause considerable difficulty, and, while some trouble has been found, this is being largely overcome as the round-house men become more familiar with the engines and expert in the packing of these joints.

There has been a type of locomotive introduced by the Borsig Company of Germany in which there are flexible wheels, these being mounted on tubular shafts through which the driving axle passes, so that, while the axles themselves are held in rigid boxes and operated from one pair of cylinders, the wheels can slide and swivel to adjust themselves to different degrees of curvature. We understand that these engines have given good service in certain localities in Europe, but we do not think that any of them have been introduced into this country.

ADJUNCTS AND DETAILS.

It is probably true that cast steel is more closely connected with the development of the large locomotive than any other single item entering into locomotive construction, and the possibility of being able to get large castings in this material has proved a very important factor in the advancement of this proposition. Some years ago steel castings were produced only in very small sizes by means of crucible furnaces, and such things as steel driving wheels, frames, foot-plates, &c., were unknown. With the large number of open-hearth steel plants making steel castings of high-grade material now in this country, there has been a great impetus given to the reduction of weight and increase of strength by substituting steel castings for iron castings, and, in many cases, for iron forgings. In the former category probably driving wheel

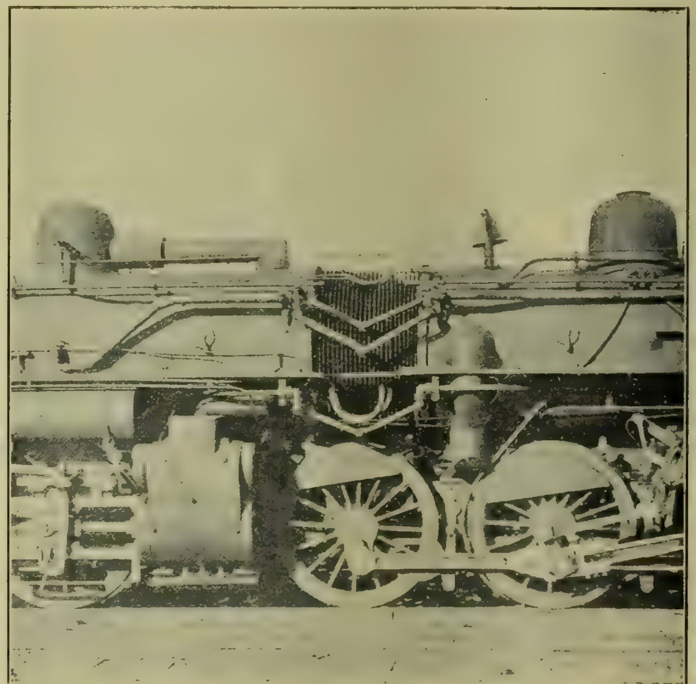


FIG. 5.—"ACCORDION" JOINT.

centres have been the most conspicuous examples, as even 10 or 15 years ago the axles and crankpins of locomotives were assuming such proportions that it made it difficult to obtain the proper strength with an iron casting. As the main driving wheel is subjected to a far greater stress than the other driving wheels, steel was first substituted in the main driving wheel only, but nowadays, when it is desirable to get the boiler as large as possible and thereby keep the other parts as light as possible, cast steel is used in many cases in all the wheels of a locomotive. It has now even become difficult to get along with cast steel, as, with the increased size of axles and pins and the inadvisability of increasing the stroke, we have got to such a point where there remains only 5in. or 6in. of metal between the axle and the pin fits, and when we consider that these are forced in with pressures from 100 tons to 200 tons it will be understood how difficult it is to produce a steel casting that will satisfactorily withstand forcing stresses and also those due to operation.

At first there was much difficulty in making driving wheels, as the rim would set in the mould long before the hub and fractured spokes would occur. This was overcome by separating the rim into sections so that the spokes could pull the rim towards the centre as cooling progressed. Later, however, the steel works found that they could cast these rims solid by uncovering the hub and arrange to cool that portion more rapidly, so as to promote uniform contraction throughout the casting.

Foot-plates have been another very important example of the use of steel instead of iron castings. In olden times the foot-plate was often made unusually massive in order to add adhesive weight to the engine, but the great desire to produce boilers of maximum capacity has led to the use of foot-plates of cast steel, thereby reducing the weight very materially, and allowing for greater boiler capacity. In such castings as these the weight of the piece in steel would be anywhere from one-half to one-third of what it would be in cast iron, and when this practice is followed through the different parts of the engine the great saving of weight is at once apparent.

Boiler supports, guide yokes, frame separators, and, in the Mallet type of locomotive, saddles connecting the frames and the cylinders, are now made of steel castings, and this metal is very much superior to iron in standing impact, and even the effects of an unexpected collision.

In the replacement of forgings, cast steel has also rendered an important service; the most notable example of this is in locomotive frames. For years these were made of iron worked under the steam hammer, and, as the frames were of large sections, it was very difficult to properly weld the pedestals and braces together. When the sections were not over 4in. in thickness there was little difficulty, but even then it was found that the welds, in spite of the best care, had often been imperfectly formed, and would, in service, pull apart. With 5in. frames, which are now common, and 6in. frames, which are being introduced, this work would be very difficult, but cast steel permits the use of a section of almost any size. Then, too, the braces and all the parts are cast in one solid piece, so that there is less fitting and less opportunity for parts to become loose and work upon each other when the engine is in operation. Many of the more complicated forgings, such as equaliser beams, frame braces, and parts that have been made in the blacksmith shop, are now constructed of cast steel, often reducing the weight and at the same time the cost of manufacture.

In this country open-hearth steel is used almost exclusively for this material, but in Europe Bessemer steel with a comparatively high phosphorus content is much in vogue. This makes a smoother casting, as the phosphorus adds to the fluidity of the metal when being poured, but Americans are rather opposed to the use of Bessemer steel in important structures on account of its known liability to segregation and to crack under sudden strains. The open-hearth steel used for locomotive castings is both acid and basic, the former, of course, requiring a higher grade of pig to be used in its production. The great difficulty with steel castings at the present time is the tendency for piping and blow-holes to diminish the strength of a section at some part where it is impossible of detection before rupture, and, while this difficulty is being gradually reduced, largely by the careful study of proper design and the introduction of large sinking heads in moulding, yet it must still be contended with and prevents us from using as high a fibre stress as we should if we could get rid of these objectionable features. Such steel has a tensile strength of from 60,000lbs. to 80,000lbs., which is fully double what can be obtained from cast iron, and, on account of its ductility and resistance to stand blows, it is superior to cast iron in even greater proportion than its increase in strength.



Fig. 6.—Oil-burning Mallet Locomotive.

As yet little has been done in the use of cast steel cylinders in locomotives, although some few have been in service. As there is a tendency toward three-part cylinders—that is, a central saddle with a separate cylinder bolted at each side—the feasibility of using steel cylinders has been greatly enhanced. Of course, such cylinders have bushings of cast iron for both the piston and the valve, and, as the latter is nearly always of the piston type, the construction of a cylinder of cast steel is not especially difficult. The recent practice of using outside steam pipes materially assists in this problem.

Following the introduction of steel castings for frames, driving wheels, driving boxes, &c., alloy steel has also made its appearance in locomotive construction, and chrome vanadium or chrome titanium is frequently possible for the parts involving heavy stresses. The latter adds very little to the cost of steel per ton, and is thought by some to be practically as efficient as the high-priced vanadium steel. Nevertheless, there is difficulty being experienced with both of these alloys, and when we consider that even the heaviest sections that we are able to produce now are hardly strong enough to stand such enormous piston loads, which in some cases reach to 140,000lbs. or 150,000lbs., the necessity for refinement in this line is apparent.

There has been little attempt to make such parts as connecting rods, parallel rods, &c., of steel castings, and the few

attempts that have been made in this line have not been crowned with sufficient success to warrant extension in these particular details. Crank axles are seldom used in this country, but it has been found that the crank-webs in a built-up axle have given very good service when made of cast steel, but the forces in such a structure produce, principally, bending and torsion where steel castings are particularly satisfactory. In connecting rods, however, there is so much tension and compression that it does not seem wise to run the risk of using a metal that may have a blowhole or pipe at some critical part, and only high-grade hammered steel is used, as a rule, in these forgings.

While the Walschaerts valve motion has been recognised for many years as a suitable means for operating the valves on a locomotive, and has been used largely in Europe, it is only recently that its application to locomotives in this country has been worked out on a large scale. There have been many essays written upon the relative advantages of the Stephenson, which has been universally used, and the Walschaerts valve motion, so far as the movement of the valve itself is concerned, some claiming the Walschaerts gear with its constant lead was a great benefit, while others claim that the Stephenson motion with its increasing lead for early cut-offs is most desirable. Personally, we are inclined to agree with the latter theory. It is well known that a locomotive with a large amount of lead is very slow in starting, whereas one with a small or blind lead will be particularly active in getting under way and being reversed. With the constant lead of the Walschaerts motion it is necessary to settle upon some amount that will be satisfactory under ordinary running conditions, and this often produces a locomotive that is noticeably tardy in handling. In the Stephenson motion it is perfectly feasible, if desired, to set the valves line and line when the reverse lever is in the corner, and have from ¼in. to ⅜in. lead when working at early cut-offs. This in itself constitutes a considerable advantage; however, it has been found by practical demonstration in road tests that there is no essential difference in either fuel economy or economy of train operation between the two methods of distribution, and for all practical purposes we can generally assume that the steam distribution and economy will be the same in both.

What, then, has given the impetus to the Walschaerts gear within the last decade, if there is no advantage to the valve movement, and, in fact, the possibility of a disadvantage? The answer is that it is simply caused by structural reasons. The Stephenson motion, with its inside links, while being well protected from damage by a side-swipe, has the disadvantage of requiring eccentrics, which, with the modern proportions of driving axles, have assumed very large dimensions, so large, in fact, that there is continual trouble in trying to keep them lubricated, as the weight and speed of the running surfaces have been increased with the enlargement of the axles. There is also considerable difficulty in suspending the link centrally, and, while it could be done, it was rather a troublesome and expensive arrangement. Perhaps the greatest incentive to remove the valve motion from under the barrel of the boiler was the fact that the heavy engines with long frames required cross-bracing, and when the eccentrics and rods are removed we have splendid opportunities for connecting together the frames with ample cross-braces. The increased weights have called for wider frames and long journals, so that there is very little space left in which to place a satisfactory inside link motion.

The Walschaerts gear overcomes both of these difficulties, permitting not only a very comprehensive system of cross-bracing, if desired, but also eliminates the eccentrics and places the motion where it is very accessible. It has been claimed that the Walschaerts valve gear has fewer pieces and weighs less than the Stephenson, but when we consider the supports necessary to carry and suspend the various parts of the Walschaerts gear there is a great deal of weight and expense which, while it is not a part directly of the valve gear, yet is necessary to support the same. This results in an increased coast for the Walschaerts as compared with the Stephenson valve gear. In many cases these supports can be worked in as part of or an extension of the cross-bracing of the frames and boiler, and produce a very simple and strong structure, and, taking everything into consideration, the change in valve gear has resulted in a very much better braced engine than was possible with the old Stephenson motion. There is no question, therefore, but that this valve motion is here to stay, in spite of the fact that many people consider the actual movement of the valve not as satisfactory as with the Stephenson arrangement.

With the large and heavy valves that must be moved in the modern locomotive the force necessary to operate the reverse lever has considerably increased. With articulated locomotives, which have two or more shifting valve motions, the work to be done is doubled or trebled; therefore, we are prepared to understand the second advent of power-reversing gears. It has probably been 30 years since the first steam reversing gear was used in this country, after a few years' use of which on a very small number of locomotives it was abandoned. In those days the valves were small, and there was no difficulty in handling them very satisfactorily with the reversing lever. Now, however, the conditions are entirely different, and, in addition to the heavy weights to be moved, the wide firebox prevents in many cases a good practical application of the time-honoured reverse lever. In some cases it has been necessary to use a power reverse simply because a satisfactory hand reverse lever could not be worked in with the type of boiler used. These considerations are of sufficient importance to necessitate the complication of the power reverse gear, so that it is not likely that it will be relegated to oblivion, as was the attempt made many years ago.

(To be continued.)

THE ASSOCIATION OF CONSULTING ENGINEERS.

THE first meeting of the duly elected members of the Association was held at the Institution of Electrical Engineers on Monday, July 22nd, Mr. G. Midgley Taylor, M.Inst.C.E., presiding. The Chairman said the business of the present meeting was to receive the rules presented at the meeting held in January and the report and proposals of the Provisional Committee, and to elect the first committee of the Association. In making the following remarks he wanted members to understand that he was not speaking for himself alone but from a document prepared by the committee and with which the committee were in absolute and full accord. They were only following the lead of the United States and Germany in the formation of an Association of Consulting Engineers to look after their own interests. If they could not look after their own interests better than anybody else he would be surprised. In the formation of an association of this nature it was only natural that certain questions should arise, and one of the most important that had arisen was, What is a consulting engineer? The committee had devoted considerable attention to the matter, and had, after consultation with their legal advisers, adopted the following definition:—

"A consulting engineer is a person possessing the necessary qualifications to practise in one or more of the various branches of engineering, who devotes himself to advising the public on engineering matters or to the designing and supervising the construction of engineering works, and for such purpose occupies his own office and employs his own staff, and is not directly or indirectly concerned or interested in commercial or manufacturing interests such as would tend to influence his exercise of independent professional judgment in the matters upon which he advises."

The next question which had been asked was, Why was it necessary to form a new association when there were such ancient and honourable institutions as the Institutions of Civil, Electrical and Mechanical Engineers? All the members present were connected with one or other of those honourable bodies, and they would remain loyal to them; but it was felt there was a necessity for the formation of a society specially devoted to the small proportion of consulting engineers who belonged to the vast numbers of those various institutions. The committee thought that probably not five per cent. of the members of the three important institutions in question complied with the definition of a consulting engineer that the committee had already laid down, and that there had, up till now, been no source from which any one could obtain definite information as to who was an independent consulting engineer and who was not. The Association, subject to the rules being amended, would be composed of those members of the three institutions on whom

the rules of professional conduct drawn up by the Institution of Civil Engineers, and since accepted by the Institution of Electrical Engineers, were always binding, as distinguished from those members who were only bound by them when acting in a consultative capacity. The Association did not suggest that any duly qualified engineer should not be consulted on any engineering matter on which he was an expert; but they did say that it should be possible to distinguish the independent consulting engineer from the expert who might be closely identified with manufacturing or contracting interests. The objects of the Association were set out in the Articles of Association, and they were, briefly, to uphold the standard of professional conduct and to promote the professional interests, rights, powers, and privileges of consulting engineers. Those objects were equally in the interests of the public and of consulting engineers, and could obviously best be promoted by the creation of such an association as this. Since the meeting in January last the committee had again reviewed the rules which had now been put into legal form by the honorary solicitor, Mr. F. W. Wright (of Messrs. Faithfull & Owen), to whom the best thanks of the Association were due. The Articles of Association and the rules, as proposed by the committee, were in the members' hands, including the alterations of the original rules, which the committee now asked the members to approve, and which were as follows: (1) That the subscription be raised from one guinea to two guineas. (2) Corporate membership of the Institution of Civil Engineers or full membership of the Institutions of Electrical or Mechanical Engineers be accepted as evidence of technical qualifications for membership of the Association. (3) That members be entitled and requested to use the abbreviation M.Cons.E. when stating their qualifications. (4) That the committee be increased to 18, of whom not more than 12 shall be London members.

The Treasurer would tell the members that the Association could not make both ends meet and become useful—by circularising members in regard to things current and probably by having some quarterly communications—if the subscription were only a guinea a year. With regard to the alteration of the rule which provided that corporate members of the Institution of Civil Engineers only should be admitted, the committee, after mature deliberation, thought they should throw their ranks open not only to corporate members of the Institution of Civil Engineers but also to full members, both of the Electrical and Mechanical Institutions. The President-Elect of the Electrical Institution, one of the most eminent men in his profession, was not a member of the Institution of Civil Engineers, and therefore, although anxious to join, would have been ineligible under the rule in its original form. After the rules had been finally approved by the meeting, the earliest opportunity would be taken to submit the Memorandum and Articles of Association for the approval of the Board of Trade and to register the Association, after which the final rules and list of members would be printed and circulated amongst the members, and Government Departments and engineering and public bodies will be notified of the formation of the Association. It was felt that the Association, as the only body representing consulting engineers, would form a useful channel through which the opinions of consulting engineers could be ascertained and with whom bodies representing other engineering interests could usefully confer. It was hoped that all members would assist the Association by reporting for the consideration of the committee any matter affecting consulting engineers which, in their opinion, could be usefully dealt with, and also by inducing all eligible consulting engineers, who had not yet done so, to join the Association. He formally moved that the Memorandum and Articles of Association, including the alterations and additions which had been referred to, should be approved and adopted. In the document in the members' hands the proposed rules were included and in addition to the specific alterations he had mentioned there were a number of new rules and a number of slight verbal alterations which had been put in by the honorary solicitor, on the advice of counsel, but they were merely formal.

The Honorary Treasurer (Mr. S. R. Lowcock) said he did not think it was likely that the Association could ever become a very large body, as the number of engineers who were eligible under these rules was, as the Chairman had already pointed out, limited. With a comparatively small membership, and an annual subscription of only one guinea, the Association would be always in difficulties, and could not be effective in the way he was sure they all desired and intended. Although it was not an association for profit, to enable it to be carried on properly, they must not only make both ends meet, but must have a small margin.

In addition to the annual expenses, the preliminary expenses, registration, printing the Memorandum and Articles of Association, and list of members had to be provided for, and from the estimates he had made, he was quite sure it was not possible to conduct the business of the Association properly with an annual subscription of less than two guineas.

Mr. Charles Bright congratulated the committee on the care with which they had considered the whole subject, but he thought a subscription of one guinea should be sufficient for an association of that kind. He did not wish his remarks taken in any spirit of animosity.

Mr. W. Fairley said he had rather expected the subscription would be raised above two guineas, because there must be an ordinary paid secretary in addition to the honorary secretary.

The Chairman said he trusted the meeting would approve of the proposal to increase the subscription. If they got a large membership they could, if thought advisable, reduce the subscription back to a guinea.

The meeting then approved the alteration and the addition (with regard to the use of the abbreviation "M.Cons.E.") set out above.

The Chairman then moved, and Mr. W. R. Cooper seconded, a resolution that the Memorandum and Articles of Association and the rules as amended and as printed in the document before the meeting be received and adopted. Before putting the resolution to the meeting the Chairman invited discussion on any points members might raise. After replying to questions by Mr. M. G. Weekes and Mr. J. H. Blizzard, the Chairman put the motion, which was duly carried.

With regard to the constitution of the committee, the Chairman remarked that the committee were anxious to have a certain continuity of action for the first year and they issued amongst themselves balloting papers for the London members, with the result that the 12 names printed in the Articles of Association received the majority of the votes. The hon. secretary and hon. treasurer were also, ex-officio, members of the committee. In accordance with the rules, one-third of the committee retired every year. The committee were not empowered to recommend names for filling up the four vacancies so created, and those who retired were not eligible, under the rules, for re-election, but it was open for any member of the Association to propose a member of the committee, and they would be balloted for at the general meeting. With regard to the country members, the selection was one that required careful consideration, and the committee asked that, in the first instance, the election should be made by the 12 London members, whose election he invited some member to move. The suggested committee included representatives of civil, electrical and mechanical engineering.

Mr. J. H. Blizzard proposed that the members suggested by the committee (Messrs. John Sydney Alford, Henry Percy Boulnois, William Tregarthen Douglass, Baldwin Latham, Ernest Lawson Mansergh, William Morris Mordey, William Henry Patchell, Henry Rofe, John F. C. Snell, Edmund Herbert Stevenson, James Swinburne and G. Midgley Taylor) be the London members of the committee for this year.

Mr. A. A. Campbell Swinton seconded, and the motion was duly carried.

The Chairman then proposed that the list of country members of the committee be left vacant for the present, on the understanding that the committee would fill the list up with the best names they could find for the provincial towns, but he invited suggestions from members. The committee felt that upon the country members would largely depend the amount of support the Association would receive from the various provinces they represented.

Mr. Weekes seconded, and the motion was duly carried.

Votes of thanks to the Institution of Electrical Engineers (for the use of their rooms), to the hon. secretary (Mr. A. H. Dykes), to the hon. solicitor (Mr. F. W. Wright), and to the chairman (Mr. G. Midgley Taylor) closed the proceedings.

THE TESTING OF MOULDING SANDS.*

BY ALFRED B. SEARLE.

WHENEVER a material is used which occurs in a natural state, it is usually subject to variations in character which may utterly spoil it for the purposes for which it is employed. The sands used by moulders ought, therefore, to be tested in some way in order to minimise the losses which would otherwise result from the use of unsuitable sand. The necessity for some form of testing is recognised in an indefinite manner by every moulder, and some of the "tests" applied in the shops are of value, though very crude and limited in scope. On the other hand, moulders have generally failed to recognise the necessity for more complete knowledge of the sands they use, and many of them are, in consequence, paying more dearly for their sands than would be the case if they were tested properly. One particularly striking example occurred recently in the experience of the writer, in which a firm were purchasing sand from 140 miles distance when a sand more suitable for their purpose, but of a less attractive appearance, could be obtained from a pit close to the works. In this instance a certain amount of prejudice existed, for the foreman moulder was accustomed to a particular sand and did not see fit to change when he entered the employment of another firm. It was only when the characteristics of the two sands had been closely compared that their practical identity was proved and they were used with success on a commercial scale.

The lack of information on the subject of testing makes it difficult to lay down a complete series of tests, for the requirements of different shops differ very greatly and the idiosyncrasies of different moulders must also be considered. For instance, in one shop in which the writer is interested, three different moulders used three different sands, and could not, for a long time, be persuaded to change. Even that most cruel test of all—the secret substitution of one sand for another—failed to overcome the difficulty as soon as the substitution was discovered, though during the three months it remained unknown no noteworthy troubles occurred.

The chief measurable characteristics of moulding sands are (*a*) refractoriness, (*b*) porosity, (*c*) permeability, (*d*) fineness, and (*e*) strength when formed into a mould. It will be observed that these are all physical properties, yet they are, to some extent, dependent upon the chemical composition of the sand, and this must therefore be taken into consideration.

Chemical Composition.—To a large extent this has been misunderstood, and analyses of sands have therefore been made on lines which are not to the best interests of the moulder. For example, the composition of a typical moulding sand will usually be reported as follows:—

	Per cent.
Silica	84·13
Alumina	9·42
Iron oxide	4·41
Lime	1·73
Alkalies	0·31
Total	100·00

In the first place it will be observed that the analysis adds up to precisely 100·00, a feat of skill almost impossible even to the ablest analyst, and an almost certain sign that some constituent has been "estimated by difference." This is a convenient way of stating that the analyst has been too lazy, too busy, or too ill-paid to make a proper analysis, and has determined the silica, alumina, iron oxide and lime, and has then found that 0·31 per cent. of material remains unaccounted for. He therefore describes this "difference" as "alkalies," and soothes his conscience with the thought that so small a percentage of any ingredient can make no appreciable difference in the value of the sand. This method of working is all the more usual because the labour attending an actual determination of the alkalies is equal to that required for all the other constituents put together.

For some purposes, such as glass-making, an accurate knowledge of the proportion of alkalies is unimportant providing that the sand is otherwise pure; but for moulding, the presence of lime, magnesia, and alkalies—even in small quantities—has a notable effect on the heat resistance of the sand, and their proportions should be ascertained with great exactitude. It is, as a matter of fact, less important to know the proportion of silica than of alkalies, and if so complete an analysis cannot be obtained on account of the cost or labour involved, it is better to treat the sample with hydrofluoric acid until all the silica has been driven off and to analyse the residue, than it is to make a guess at the proportion of alkalies, as is so frequently done.

A further serious defect of the ordinary method of reporting the results of an analysis in the form given above is that it does not give the information required by moulders.

Sands are essentially composed of three groups of substances, (*a*) quartz, (*b*) clay, and (*c*) other minerals. Of these the quartz is the main constituent, its grains being bound together by the clay; the "other minerals" may be regarded as impurities. The quartz (if pure) is composed entirely of silica, but all the silica in a sand is not in this form. Some of it occurs in combination with alumina in the form of clay and the remainder in combination with lime, magnesia, iron, and "alkalies" forming "other minerals," the nature of which must be determined (if necessary) by a careful microscopical examination.

Many attempts have been made to resolve sands into their constituents, quartz, clay, and other minerals, but no chemical method yet devised has proved satisfactory. Bischof and Seger, some 30 years ago, devised what is known as a "method of rational analysis," in which the material is treated with boiling sulphuric acid and then with caustic soda. These investigators thought that the clay alone would be dissolved by this treatment, but it has since been proved conclusively that the method is quite unreliable except for relatively pure china clay—a material of little or no interest to moulders.

If "rational analysis" gave correct results these would agree with the results of an ordinary or ultimate analysis which is known to be obtained by correct methods. In actual practice, however, the two results differ so largely that it is very unwise to place any reliance on the results of rational analysis.

In a Paper by Mr. J. Shaw in the April, 1910, issue of the "Foundry Trade Journal," both ultimate and "rational" analyses of a number of sands are given, though the former are far from complete. In none of the analyses given by Mr. Shaw do the results of the two methods tally, and a careful comparison will show such serious discrepancies in the "rational analyses" as to necessitate their being abandoned.

Some idea of the mineralogical composition of a sand may be gained by assuming that the alkalies, lime, and magnesia are all in the form of felspar, and then calculating the proportion of alumina and silica corresponding to this assumed felspar. Any excess of alumina may then be calculated to "clay" (Al_2O_3. 2 SiO_2. 2 H_2O), the silica corresponding to this deducted from the silica not in the form of felspar, and the remaining silica may then be assumed to be quartz. This method—due to Fresenius—gives results which are no less accurate than the "rational analysis," but they are subject to the serious objection that felspars do not contain magnesia and that in some sands the bases are present as mica and other minerals. Hence the only method which is at all reliable consists in a careful microscopical examination of the sand and in deducing from this the proportion of the different minerals present. Needless to say, this is a very arduous task and one beyond the skill of any but an expert.

The basis and chief constituent of sand is one of several forms of silica. It is seldom pure in moulding sands and the presence of iron oxide, lime, and other substances materially detracts from its value. Broadly speaking, the more pure quartz a moulding sand contains the higher will be its value.

"Other minerals" is a large term, and includes the small grains of almost every kind of rock, but particularly of rocks of igneous origin. In moulding sands it is extremely difficult to identify the various minerals present and this identification is, in consequence, seldom attempted.

There is, unfortunately, a strong tendency on the part of some foundrymen to assume what is convenient rather than to investigate whether such assumptions are correct. This is particularly noticeable when a discussion arises on the mineral constituents of sands. It is only misleading to assume that the greater part of "other minerals" in sand are composed of felspar,

* Paper read at the British Foundrymen's Association Annual Convention, Cardiff, August, 1912.

and a number of erroneous conclusions have in consequence been made with regard to moulding sands.

Comparisons of the proportion of alumina in various samples, though very common, are particularly misleading, as the alumina is a constituent of many minerals occurring in sands, and the extent to which it is present gives no idea whatever of the amount of the mineral of which it forms a part.

It is in consequence of these difficulties that the greatest caution is needed before an opinion as to a sand can be rightly expressed, and it is quite true to state that, at the present time, there is no simple means of ascertaining the true composition of a sand or loam; expert knowledge of micrography, as well as of analysis is essential.

Clay is an almost invariable constituent of British sands, although in some of them it must be present in very small proportions. Some idea of the amount may be gained by shaking up the sand with 20 times its weight of water in a tall glass cylinder and noting the amount of matter remaining in suspension after one minute. The test is vitiated by the extremely fine sand present, some of which will remain in suspension for an hour or more.

One of the most valuable characteristics of clays is their plasticity, but, unfortunately, no one has yet succeeded in measuring this property in a really satisfactory manner when the clay is mixed with a large proportion of sand. So little is known of plasticity that it is by no means clear that it has any connection whatever with the composition of the material. Two clays may have the same chemical composition, yet their relative plasticities may be widely different.

It was thought at one time that the power possessed by clay of binding or absorbing certain aniline dyes might provide a mean for determining the proportion of clay present, but more careful experiments have shown that this method gives very irregular results with different sands, though useful in checking the clay-content of different batches of the same sand. Further investigations are now being made in this direction.

The writer has examined many sands for various purposes and has found that a carefully arranged system of washing is the simplest means of separating the clay from the other constituents. This may be most readily carried out by stirring a convenient quantity of sand with water in a small tank containing paddles. The overflow from this tank is received at the bottom of a larger conical tube in which the water flows at the rate of 0·43in. per minute. This is sufficient to carry away all the clay together with a little of the finest sand. The product is never pure, and usually contains half its weight of sand, but this is the purest product at present obtainable. To obtain the best results very small quantities of sand must be employed, and a Schoene's elutriating funnel used. Various processes of sedimentation have also been tried, but are less satisfactory. Unfortunately, no means of definitely separating the extremely fine grains of sand from those of the clay have yet been discovered, as their specific gravities are almost identical, and no chemical reagent is known which will attack either the clay or the sand without interfering with the other. The errors of "rational analysis" have already been pointed out.

The colour of moulding sands is unimportant, except as a rough guide to the form in which the iron is present, red sands indicating free ferric oxide. This oxide is understood to assist in putting a good "skin" on castings, but it has the serious disadvantage of being reduced by the coal or coke dust mixed with the sand, thereby forming fusible ferrous silicates which bind the sand grains into lumps, and when sufficient of these are present, rendering it "dead" and useless. Various oxidants are used to prevent the occurrence of this reduction or to "revive" the sand in which it occurs; it is, however, better to use sand containing less iron oxide and never to use that which contains more than 5 or 6 per cent.

Refractoriness or resistance to heat in a sand depends on the proportion of "other minerals" present and on the fineness of the grains of quartz, &c. Sand is usually so refractory that a direct test of its heat-resisting powers is of little value. The writer prefers to separate the sand into two portions by means of a No. 150 or No. 200 sieve, and to test the heat resistance of the material which passes through the sieve. In this way, the coarser refractory particles are removed, and the finer and more fusible ones are isolated, so that their presence and effects are more marked. As it is not the absolute refractoriness that is required, but only the tendency of the sand to vitrify or fuse in places, this separation of the more fusible constituents is of value.

The fine material (or if preferred the original sample) is mixed with a little dextrine and water, and is moulded into a small pyramid about 2½in. high, with a triangular base with ⅝in. sides. This pyramid is heated is a test furnace along with Seger cones, and the number of the latter corresponding in behaviour with the test piece is taken as the refractoriness of the sample.

The porosity of a moulding sand is of smaller importance than is generally supposed. It is not the number or size of the pore-spaces between the solid grains of the sand, as received, that matter, but the facilities for the escape of gases offered by the sand when made into a mould. A sample of sand may be very porous when placed in a test glass or cup, but it may be very unsuitable for moulding because, when rammed to form a mould, the gases cannot escape. The writer has made numerous comparisons, but has been unable to trace any direct connection between the porosity of sands "as received" and their suitability for moulding. He therefore regards a porosity test as of minor importance.

The permeability to gases of a mould made of sand, on the contrary, is of great importance, and no tests of moulding sands can be complete without it. Unless the gases formed during casting can escape with sufficient rapidity, "scabs" are formed, and defective castings are produced. The permeability of a mould depends partly on the shape of the casting and on the skill of the moulder, as well as on the sand mixture used, and in any test of this property due importance must be attached to the "personal element." The writer has obtained the best results in the following manner:—

A mould case is used which consists of a circular metal box 3in. diam. and 1¼in. deep, with the bottom cut out and replaced by wire gauze of any convenient mesh. On the bottom of this case a sheet of thin porous blotting-paper is laid and the case is filled with sand to be tested, care being taken to ram it in a manner as similar as possible to that employed when an ordinary casting is to be made. The sand or sand mixture should be precisely 1in. thick. In order to preserve the conditions of normal ramming the writer frequently places the empty test case in a larger mould in course of formation, and removes it when filled, the space left in the larger mould being afterwards repaired. The case is filled by laying on a second sheet of paper, and by inserting a flanged pipe, the whole being then clamped firmly, but without breaking the structure of the sand. Water is poured into the flanged tube to a height of 40in. and the appliance is suspended above a glass receiver or measure. The time taken for 100 c.c. of water to flow through the sand into the receiver is a measure of the permeability. In exact experiments the level of the water in the flanged tube must be kept constant.

If care is taken in making the test, results from similar sands are very constant, but test blocks made by different moulders differ so greatly that no comparison is possible. Hence in testing fresh deliveries of sand it is important that all the test pieces shall be made by the same moulder. At the present stage this test is of value in works for the manager's own use, but not for comparison with the results obtained by others; the differences caused by unconscious variations in manipulation are too great. In a modification of this test the writer endeavoured to substitute air in place of water, but the variations in the amount of air penetrating through the same block at different times as well as with different tests of the same sand made the use of air appear to be impracticable. Further experiments are, however, being made in this direction.

The fineness or size of grains of sand used for moulding has never been standardised and equally good results have been obtained with sands of most divergent characteristics in this respect. In comparing the fineness of different samples of sand, the writer has found an adaptation of Jackson's "surface factor" is convenient, providing the material is not too coarse. The writer has for more than 10 years used a series of sieves with 10, 25, 50, 100, and 200 holes per linear inch.

Since the standardisation of sieves by the Institute of Mining and Metallurgy, it is best to use standard sieves; these are made by N. Greening & Son, Warrington. The sizes of the apertures of the sieves are given in a subsequent table.

The sand is mixed with water, well shaken for half an hour or more in a mechanical agitator and then run on to each of the sieves in turn. Each sieve is then washed with a powerful "rose" of water so as to ensure all the sand finer than the mesh running on to the next finer sieve. The contents of the various sieves are then dried and weighed. The material which passes through the finest sieve contains all the clay together with an equal weight or more of sand. This mixture is placed in a Schoene's elutriating tube, and water is passed through it at the rate of 0·43in. per minute. In this way a further portion of very fine sand remains in the vessel, the clay with some sand being washed out by the water. This clayey portion is collected, dried, and analysed; its composition will give a fair idea of the proportion of clay present.

The surface factor is found by multiplying the weight of each fraction separated in this manner by an appropriate factor, and adding all these numerical products together. The factors for multiplying are shown in the following table, from the writer's "Clayworkers' Handbook":—

	Sieve.	Diameter of particles.	Nature.	Factor.
A	On sieve No. 1........	Above 0·5in.	Stones	*Nil.*
B	Between sieves Nos. 1 and 10.	Above 0·05in. to 0·5in.	Gravel	0·27
C	Between sieves Nos. 10 and 50.	Above 0·01in. to 0·05in.	Course sand.	2·6
D	Between sieves Nos. 50 and 100.	Above 0·005in. to 0·01in.	Medium sand.	13·2
E	Between sieves Nos. 100 and 200.	Above 0·0025in. to 0·005in.	Fine sand.	22·6
F	Between sieves Nos. 200 and washing.	Above 0·0004in. to 0·0025in.	Silt........	53·9
G	Washed out by a stream 0·43in. per minute.	Below 0·0004in.	Clay and dust.	359·0

If the weight of each fraction be represented by the letters in the first column in the above table, the surface factor is

$$0{\cdot}27B + 2{\cdot}6C + 13{\cdot}2D + 22{\cdot}6E + 53{\cdot}9F + 359G.$$

The finer the sand, the higher will be the surface factor. As the factor for stones is *nil* the weight of stones present does not enter into the calculation except in so far as it reduces the total forming the surface factor.

The use of this factor in comparing several well-known moulding sands is exemplified in the following table, in which the letters indicate the proportion of each of the grades, as above:—

Sand.	A.	B.	C.	D.	E.	F.	G.	Surface factor.
Medium Erith	—	0·03	1·19	0·34	42·74	28·52	27·17	12,205
Fine Mansfield	—	—	1·50	3·92	40·63	31·73	22·21	10,657
Coarse Mansfield	0·01	0·74	3·36	18·42	67·17	6·49	3·81	3,497
Stourbridge	—	0·22	5·36	18·93	54·76	14·64	6·08	4,472

By means of this surface factor a single expression is used for the fineness of a sample of sand and a ready method of comparison is obtained. The difference in texture between the fine and coarse Mansfield sands is well shown in the table, the Erith sand corresponding with the former and the Stourbridge with the latter.

The sharpness of sand cannot be expressed numerically, but a careful microscopical examination will usually enable the relative angularity of the grains of two samples to be determined in a few minutes.

The strength of sand when in the form of a mould is another property for which no satisfactory method of measurement has been found. The measurement of the tensile strength of test pieces made with fixed weights of sand, water, and dextrine has not proved satisfactory, and the sand, as actually used by moulders, has so little compressive or tensile strength that the errors of experiment are so great as to destroy the value of the results. The writer has ascertained the maximum weight which can be carried by a cube of sand of 2in. sides, the weight being applied in the form of a light aluminium cylinder with a large base. Water or mercury is run into the cylinder until the cube of sand loses its shape. So far the results, though interesting, are far from constant with different batches of the same sand, though consecutive cubes made from a small sample yield constant results.

Dead sand is that which has been mixed with coal dust, has been used a number of times by the moulders and has lost its valuable properties. Dead sand is deficient in plastic clay, as may readily be seen by examining the finest portions removable from the material by a slow stream of water. It also contains a larger proportion of sand grains which have been fastened together by the fusible silicates produced by the reaction of the coal dust on the iron oxide and silica in the material. Dead sand has a very low surface factor—in the specimens examined by the writer this varied from 437 to 1,025—and as it does not pay to grind it and so increase the surface factor, dead sand can only be used to a very limited extent along with new sand.

In spite of the difficulties experienced in testing sands and in formulating satisfactory conclusions from the results of such tests, their value is unquestionable, and as users of moulding sands accustom themselves more and more to the study of the properties of the sands they use, the greater will be the progress made in obtaining satisfactory castings. In Germany, where the use of artificial mixtures of various sands is common, the writer has found an increasing tendency to detailed standardisation of the different sands employed; in this country, on the contrary, moulders are blessed with natural sands of sufficiently suitable composition and physical properties, and there is less inducement to improve these natural materials. Nevertheless, a careful study of the tests suggested in this paper, combined with that of actual castings produced from known sands and mixtures, has convinced the writer that the use of such improved sands is one of the great needs of the industry at the present time. The chief difficulty is that the most effective tests are beyond the capability of the ordinary foreman, whilst those who have the ability for carrying them out do not have access to a sufficient number of foundries to be able to draw general conclusions. It would be well if this Association could undertake a general investigation into the matter.

THE INSTITUTE OF METALS.

NEXT month the annual autumn meeting of the Institute of Metals will be held in London for the first time since the Institute's formation in 1908. In that year the Institute met in Birmingham; in subsequent years meetings were held in Manchester, Glasgow, and Newcastle-upon-Tyne. This year it is London's turn to welcome the members of this, the youngest, but certainly not the least virile, of our scientific institutions. Arrangements for the meeting to be held on September 25th and 26th are in the hands of an executive committee composed of the London members of the Council of the Institute, who have drafted an attractive programme. The meeting, for which ten papers have been prepared, will open at 10-30 a.m. on Wednesday, September 25th, and will be held at the Institution of Electrical Engineers, Victoria Embankment, W.C. During the morning a series of papers will be read and discussed, Prof. W. Gowland, F.R.S., Assoc. R.S.M., president, being in the chair. In the afternoon members will proceed either to the works of Messrs. Fraser & Chalmers, Ltd., Erith, or to the National Physical Laboratory, both of which will be open to their inspection. In the evening there will be a reception by the President of the members and their ladies, which will take place at the Royal United Service Institution, Whitehall, S.W. On Thursday, September 26th, papers will be read and discussed at the morning session of the Institute at the Institution of Electrical Engineers, and in the afternoon alternative excursions will take place, one being to Woolwich Arsenal by special steamer from the Embankment, and the other being a visit to the Brooklands motor racecourse and aviation ground, special motors being provided for the conveyance of the party. Weather permitting, aeroplane competitions will take place for the Institute of Metals aviation prize. Anyone desiring of taking part in the meeting should communicate with the secretary, Mr. G. Shaw Scott, M.Sc., Caxton House, Westminster, S.W.

THE INNER STRUCTURE OF SIMPLE METALS.*

BY SIR J. ALFRED EWING, K.C.B., LL.D., F.R.S.

(*Continued from page 149.*)

THE crystalline constitution of the grains, then, survives severe straining. How does it do so? That is a question Dr. Rosenhain and I set ourselves to answer. We tested specimens of metal by straining them actually under the lens of the microscope and observing what happened during the process. The specimen was a thin strip of sheet metal, which was strained in such a manner that the same crystals were kept in view the whole time. In Fig. 1 we had a specimen

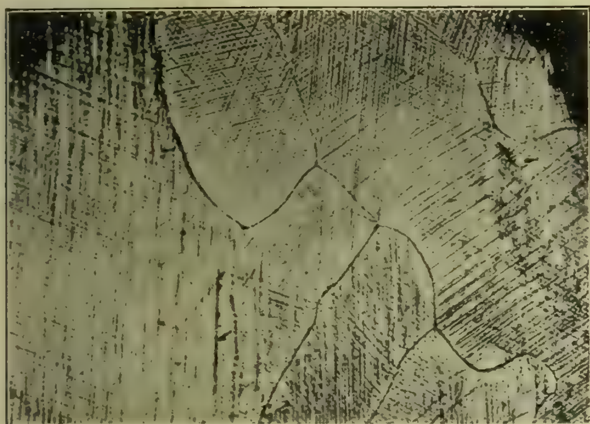


FIG. 11.—LEAD AFTER STRAINING, SHOWING SLIP BANDS. Magnified about 60 diameters.

of iron lightly etched. This was subsequently strained by tension, but the photograph of Fig. 1 was taken before the straining began. In Fig. 10 we have identically the same grains after a slight amount of straining—enough to carry it beyond the elastic limit, but not much beyond. If we compare those two accurately by applying compasses and measuring the lengths of the grains, it will be found that in Fig. 10 each grain has become a little stretched in one direction and a little shortened in the transverse direction. But that is not the main difference. The main difference produced by the straining is that over the surface of each grain a number of curious black lines have appeared, almost like the crevasses of a glacier, lines which are substantially straight and substantially parallel. It is in virtue of these lines that the plastic strain of the crystal grain has happened. These lines mean not that crevasses are formed, for there is no rupture of continuity, but that there has been shearing at a corresponding number of internal surfaces, that the crystal grain has behaved as a pack of cards behaves when you try to make it alter its form. The pack of cards becomes strained by the slipping of one card on the other, of each layer on its neighbour. In precisely the same way the crystals of metal become strained by the slipping of the little brickbats of

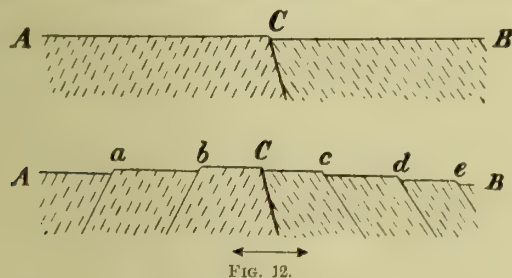


FIG. 12.

one layer on those of the adjacent layer within each grain. The result is that on the polished and etched surface little steps are formed by the slipping, and it is these little steps that constitute the black lines you are now looking at. They are narrow bands rather than lines; Dr. Rosenhain and I, when first we discovered them, called them "slip bands."†

Perhaps you will realise the nature of these lines better by looking at another specimen of strained metal. Fig. 11 shows under a power of 60 diameters a specimen of lead in which one got a beautifully smooth surface, and then severe straining brought out the slip bands or slip lines. I compared the action just now to that which occurs in a pack of cards, but the comparison is a very incomplete one. In order to admit of the changes of form that are brought

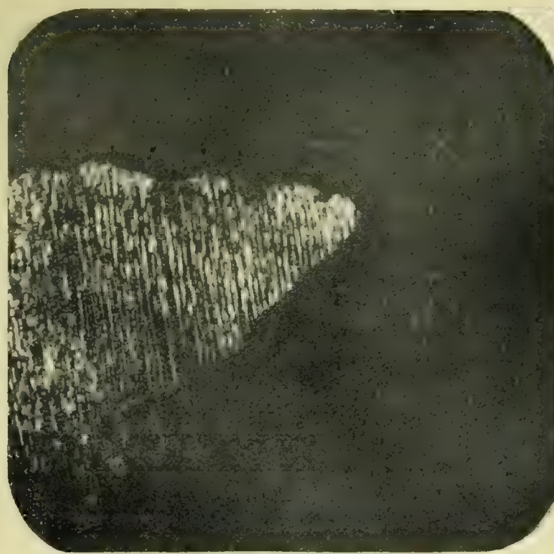


FIG. 13.—LEAD AFTER STRAINING, WITH SLIP BANDS SHOWN BY OBLIQUE LIGHTING. Magnified 100 diameters.

about by straining, one must have slips not only on one system of planes, but on several systems—on three systems at least in each grain in order to get such complete distortion as may occur. It will be noticed in Fig. 11 that in some of the grains four distinct systems of slip lines are visible. These have been carefully traced, and it has been found that they represent slips on the four octahedral planes of the cubic crystals of which the lead is composed.

The process which I have attempted to describe may be illustrated by a very rough diagram (Fig. 12). This is an imaginary section through a couple of crystal grains. The line at the top represents the polished surface which we are looking at from above in the microscope, AC being part of the surface of one crystal grain, and CB that of another. The dotted lines represent the manner in which the layers of brickbats are disposed in the two crystals. Now, imagine that straining takes place so as to stretch the whole thing

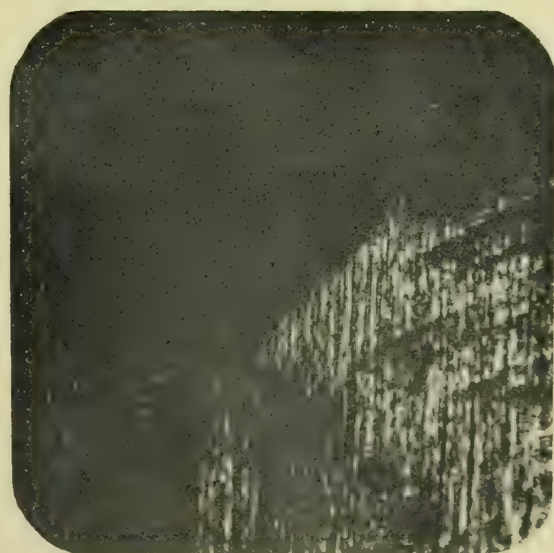


FIG. 14.—SAME SURFACE AS FIG. 13, BUT WITH DIRECTION OF LIGHTING ALTERED TO SHOW SLIP BANDS ON A NEIGHBOURING GRAIN.

in the direction AB; the result is that every here and there in the crystal CB slips will take place (as at *c*, *d*, and *e*), the part to the right slipping down relatively to the part to the left. Similarly in the crystal AB slips take place at *a* and *b*, the part to the left slipping down relatively to the part to the right. In consequence of that you get a number of steps formed on the polished surface. One such step has

* Lecture delivered before the Institute of Metals, May, 1912.

† Ewing and Rosenhain, "Proceedings of the Royal Society," Vol. LXV, p. 85; "Philosophical Transactions," Vol. CXCIII., 1899, p. 353.

been formed at *a*, another at *b* parallel to it, and so on. When you look at the surface through the microscope, throwing the light directly down upon it, the light which falls on those parts of the surface between the places where slip has occurred is reflected up again into the microscope, and those

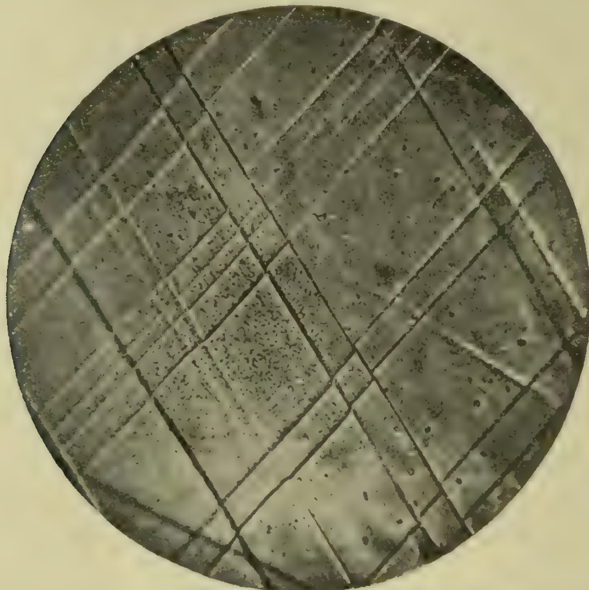


FIG. 15.—SLIP BANDS IN STRAINED LEAD. Magnified 1,000 diameters.

parts accordingly appear bright, but the light which falls upon any one of the little sloping steps is reflected away, and therefore each step appears in the microscope as a narrow dark band.

Clear proof that the slip lines are really little steps was furnished by testing the effect of oblique illumination. It will be obvious that, if the theory is correct, it should be possible, by throwing the light from the side, to get the little step which was dark in the first instance to shine up brightly. We have only to choose an appropriate direction from which the light should come in order that the step may reflect it up into the microscope. That has been done in this slide. Here are illustrations of what Dr. Rosenhain and I found when we made that experiment. In Fig. 13 we have several grains of a strained specimen of lead illuminated by light falling very obliquely from one side. The light is so placed that some of the slip lines or slip bands are bright, through reflection from the little steps up into the microscope. The light is falling on all the grains alike, but only one is visible,

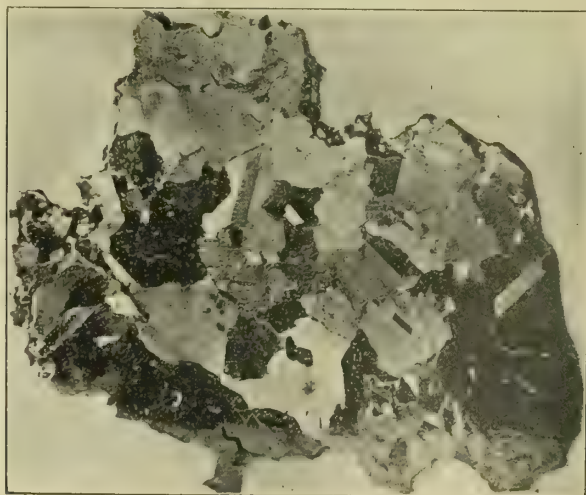


FIG. 16.—SECTION OF GOLD NUGGET, WEST AUSTRALIA. Magnified 1½ diameters (Liversidge).

because none of the slip lines on the others are favourably situated for reflection into the microscope. Now we shift round the direction of the illumination (Fig. 14): another crystal has its slip lines brilliantly illuminated, and at the same time the one that had its lines illuminated before has now become dark.

Fig. 15 is a photograph of the system of slip lines on a small part of a single lead crystal under a magnification of 1,000 diameters. You can see that the slips have produced small differences of level, and it is apparent that they have taken place successively in the different planes, so as to result in a compound system of steps.

Dr. Rosenhain gave subsequently a further demonstration by obtaining a transverse section of the steps formed by slipping. To do this he strained a piece of iron to form the lines, and then deposited a thick layer of copper upon it by an electrolytic process; finally he cut a transverse section through both the iron and the copper covering, and polished that for microscopic examination. Under a high power it was seen that the surface between the two metals had upon it a number of little definite parallel steps, which corresponded to the slip lines produced by straining the iron.*

We conclude, then, that the plastic yielding of metals under strain is due to slips occurring on the gliding planes of the crystal grains. This notion gives a key to plasticity in metals. It is not going too far to say that any amount of distortion can be accounted for by slips of this kind without requiring the continuity of the crystalline structure to be interrupted.

I do not say that there is not some disturbance of the particles in and close to the plane of slipping. Dr. Beilby has suggested that in the process of slipping a thin amorphous layer is formed as one part of the crystal slips upon another.

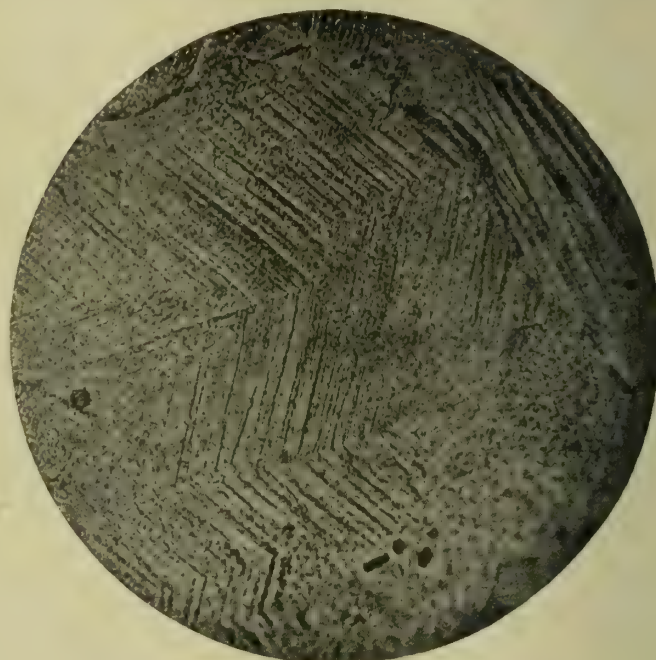


FIG. 17.—COPPER, SHOWING SLIP BANDS IN TWINNED CRYSTAL. Magnified 1,000 diameters.

The idea is consistent with the observed fact that when you have a frequently repeated succession of slips backwards and forwards you get a deterioration of the material which may ultimately result in fracture. This is the well-known fatigue of strength, caused by repetitions of straining, an immensely interesting matter about which the microscope tells us much, but to discuss it would take us too far to-night.†

A point of fundamental importance in relation to the crystalline structure of metals is the frequent presence of what are called twin forms. Twinning sometimes results as a direct effect of straining. Much more commonly it is found in a metal that has been strained and then annealed. It does not occur in all metals. It is conspicuously absent in forged iron under ordinary conditions‡ but in gold, copper, silver, or lead you often find it when the metal is in the wrought state.

Perhaps the most intelligible way to explain what is meant by twinning is to ask you to think of the process of crystal building by the piling up of layers of "brickbats" or structural units one upon the other. Suppose that after you have reached a particular layer the units which are going to be deposited to form the next layer are not laid down parallel

* W. Rosenhain, "Journal of the Iron and Steel Institute," Vol. LXX., 1906; also "Proceedings of the Royal Society," Vol. LXXIV., 1905

† See Ewing and Humfrey, "On the Fracture of Metals under Repeated Alternations of Stress," "Philosophical Transactions," 1903, Vol. CC.

‡ Namely, in α-iron; in γ-iron it is frequent.

with those that have gone before, but that every one is turned through a definite angle, let us say 180°, about an axis perpendicular to the layer, before it is laid down. If you imagine that to happen, you will have a case of what is called twin formation; the part above the plane will be in twin relation to the part below it. Very often this happens for a



FIG. 18.



FIG. 19.

certain number of layers, and then there is a reversion to the original form, and in consequence of that the surface of a cross-section, as we see it in the microscope, exhibits parallel boundaries, between which there is a band showing an entirely different texture from the material on either side, dark while the rest is light, or it may be light while the rest is dark. Whenever this characteristic appears it is to be recognised as due to twinning. Sometimes you find a series of parallel bands, each of which is a twin to its next neighbour.

By way of illustration, I reproduce in Fig. 16 a photograph, published some years ago by Prof. Liversidge,* showing in section an Australian gold nugget in its native state. Here the grains are comparatively large, and several of them are characterised by the presence of twins. On one of the grains you see a beautiful example where the twin does not extend across the whole grain, but is isolated on all sides. The photograph as reproduced is only a little larger than the natural size.

When we strain a twin piece we get a very interesting manifestation of its twin character by finding that there is a sudden change in the direction of the slip lines. Instead of running straight across the crystal parallel to one another, they suffer a sharp change of direction where they pass into the twin-band, and then revert, with equal sharpness, to their original direction, where they pass out of it. Fig. 17 is an example of twins in wrought copper which has been strained

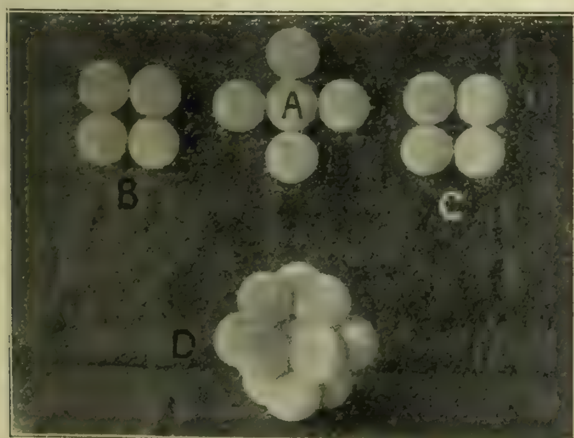


FIG. 20.

so as to develop the slip lines: notice the sudden change in their direction as they pass across the planes on which twinning has occurred. When there is a succession of parallel twin bands you get an appearance that recalls the herring-bone pattern of a parquet floor.

I have mentioned this subject of twinning at some length, because it seems to me to have an important bearing on any conjecture we may frame as to the manner in which the structure of the crystal is made up. What little time remains must be devoted to speculative consideration of the inner nature of the structure—to what Kelvin has called the molecular tactics of the crystal. We have seen that the crystal grains of metal, like any other crystals, are composed of units —units of finite size which are arranged in a perfectly regular manner. The structural units are set in rows, the rows are set in layers, and the layers are piled on top of one another. We have, as I have said, a "homogeneous assemblage," like the well-drilled flowers on a mid-Victorian wall-paper, or like what soldiers on parade would be if all soldiers were precisely alike and were spaced with perfect exactness. What are these structural units? We do not know whether they are the molecules of the metal or whether they are aggregations of molecules, and, so far as the present enquiry is concerned, I do not think it very much matters. Even if they are the molecules, there can be no doubt that they themselves possess a somewhat complex structure. We may picture to ourselves each unit as having within itself a quality of direction so that it can be oriented in a definite way. We do not think of it simply as a uniform sphere without directional quality. It may be regarded as having externally the form of a sphere; in any case that is a convenient way of geometrically representing the fact that in crystals of the types with which we are now concerned the units are spaced in regular rows at a uniform distance apart. Whatever be the real nature of the structural units, their spacing relatively to one another is that which would be assumed by equal spheres in contact. Moreover, we have to think of the particles as being capable of turning; in that respect also they behave like spheres.

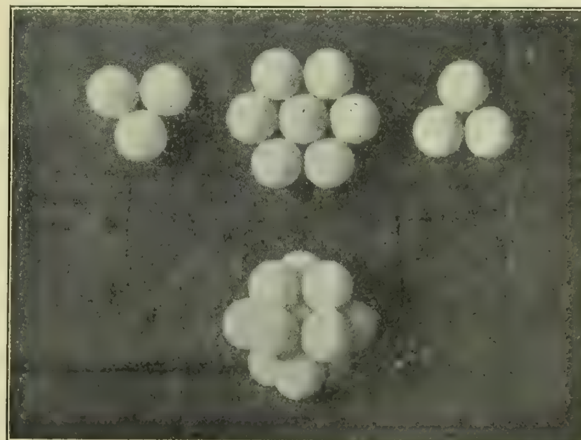


FIG. 21.

We accordingly represent the homogeneous assemblage of particles by means of balls in contact with one another. The question then arises, how may we pile spheres in contact with one another so as to build up structures that will possess those types of symmetry which we observe in metal crystals?

Before attempting to answer that question, I wish you to realise that the symmetry which is the fundamental characteristic of crystalline structure is not symmetry of external form but of internal grouping, namely, of the arrangement of the structural units amongst themselves. Symmetry of external form may, under favourable conditions, result from symmetry of internal arrangement; but you may have the latter, which is the essential thing, without the former, as, for example, in the grains of a metal where the external form is interfered with by the simultaneous growth of neighbouring grains. It is symmetry in the assemblage of the structural units that distinguishes a piece which is crystalline from one that is amorphous or non-crystalline. And it is through differences in the kind of symmetry under which the units may be assembled that we distinguish one type of crystal from another. Thus, for instance, you may assemble balls in contact with one another in more than one way, and certain of these assemblages, as we shall see presently, satisfy the condition of complete cubic symmetry, possessing 13 axes and 9 planes of symmetry, and so constituting the most symmetrical assemblage which it is possible to produce.

* A. Liversidge, "The Crystalline Structure of Gold and Platinum Nuggets and Gold Ingots." "Journal of the Chemical Society," 1897.

Another somewhat different mode of assembling the balls in contact gives symmetry of the hexagonal type.

These, the cubic and the hexagonal, are the two systems of crystallisation with which we are particularly concerned. Nearly all the metals belong to one or the other; and most to the cubic system. As Osmond and Cartaud have shown, iron in each of its three allotropic forms is cubic,* and so are gold, silver, copper, lead, platinum, iridium, osmium, mercury, chromium, nickel, and other metals which are less common. Among hexagonal metals are zinc, cadmium, and magnesium.

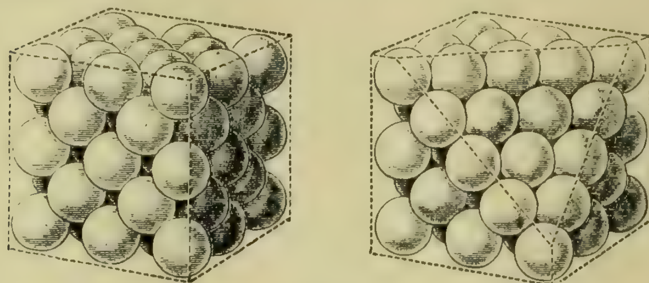


FIG. 22.

Consider first the grouping that will give cubic symmetry, which is the highest degree of symmetry that any crystal can possess.

There are three possible ways, and three only, in which particles may be piled so as to possess this symmetry. Imagine yourself to be piling balls, such as these ping-pong balls upon the table, and to aim at securing the symmetry of a cube. The first and simplest way is to pile them so that each ball is in contact with six neighbours. Take, for instance, a layer of balls put together as in Fig. 18, and put another exactly similar layer over it, ball upon ball, and another layer over that, and so on. You get in that way the simplest mode of piling with cubic symmetry, and also the most open mode you can possibly have. In this case, when you extend the group indefinitely, you find that each ball is in contact with six others. Or you may take a more intimate mode of piling, in which each ball is in contact with eight others. Here is an example of it (Fig. 19), where for the sake of clearness I have painted half the whole number of balls red, and left the others white. When you come to look at this model you will see that inside the eight red balls there is one white ball, and inside the eight white balls there is one red ball; and similarly if we went on piling them we should find that every red ball had eight white ones touching it, and every white ball had eight red ones touching it. In this mode of piling, which also satisfies cubic symmetry, you have each ball in contact with eight others.

Now we come to another mode much more interesting than either of those, the mode which yields the closest packing we can get with spherical balls, in which each ball is in contact with twelve others. Suppose that you take one ball A (Fig. 20) and place four balls in contact with it, as shown in the figure, and take four others as at B and lay those four on top of the first group in such a manner that all four come into contact with the ball A. Then take another four (C) and put them below the first group, so that they also all come into contact with the ball A. You will have a pile resembling a mulberry, as at D, in which the ball in the centre is in contact with twelve.

You may get precisely the same result in a different manner, which is illustrated in Fig. 21, namely, by placing the balls in layers in "triangular order," so that the centres of any three contiguous balls in the layer are at the corners of an equilateral triangle, and then laying these layers on top of one another so that each ball in any one layer rests in the hollow made by three balls of the layer below. Take the first ball, and put six around it as in the central upper group in Fig. 21. Take three others, forming an equilateral triangle, and put them below the six, so that they all touch the central ball of the first group. Then take three others, and lay them on top so that they too shall all touch the central ball. You will observe that there are two possible positions in which you can place them to do that. You can place them so that they lie parallel to the position they occupy in the figure, or you can turn the three on top round through 180°, so that each of them lies exactly vis-à-vis to one of the three balls which make up the bottom layer. That is a very important distinction. If we pile up our mulberry—which is precisely the same mulberry as we had in the previous case—by placing the three layers in the manner indicated in the upper part of the diagram, we get the condition of cubic symmetry satisfied. I think this was first explicitly shown by Mr. Barlow, in one of the earliest of his important studies of the geometry of crystal symmetry.*

* F. Osmond and G. Cartaud, "Annales des Mines," Vol. LXXI., 1906.

From one of his papers I take the next diagram (Fig. 22) to show definitely how we get the form of the cube and also the form of octahedron by piling balls in such a way as to have closest packing. Here we have layers of closely packed balls arranged in triangular order, laid, as you see, in a sloping position one against another, and we get the cube, as in the figure on the left. By omitting those balls which would otherwise form a corner of the cube, as in the figure on the right, we exhibit a layer parallel to a face of the octahedron. Observe that it is on the octahedral planes that the balls lie most closely; it is on them that they lie in triangular order. It is on the octahedral planes in the cubic metals that slipping occurs, and it is on these same planes that twinning occurs.

Fig. 23 represents our two mulberries again, with the difference I indicated just now, which we get by selecting one or other of the two alternative positions for the third layer. If we place the third layer immediately vis-à-vis to the first layer, as in the group to the right, we get hexagonal symmetry. If we place it as in the group to the left, we have a homogeneous assemblage possessing cubic symmetry. The closeness of packing is equal in both cases. This distinction of course holds however much we extend the group by adding more balls in each layer, and by adding more layers; in the hexagonal system the balls are vis-à-vis in the first, third, fifth layer, and also in the second, fourth, sixth layer, and so on. You will appreciate the distinction readily if you pile actual balls; when you come to place one layer over another,

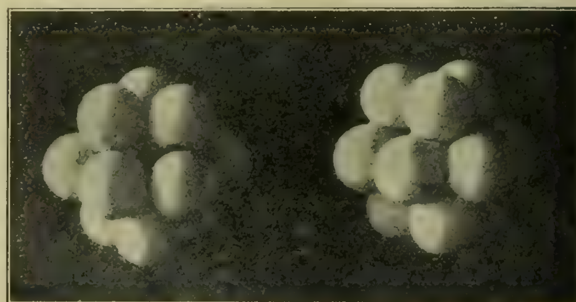


FIG. 23.

you find that there are two possible situations for the balls. By choosing always those places that are not vis-à-vis to the balls in the last layer but one, you get an assemblage with cubic symmetry.

(*To be continued.*)

* W. Barlow, "Nature," December 20th, 1883.

Accident at Barrow Ironworks: Three Men Fatally "Gassed."—At Barrow Iron and Steel Works a serious accident happened last week-end. A gang of men were engaged in clearing the gas tubes leading from the blast furnaces to the boilers on the steel works side. This work is done periodically, and has to be carried out with care. Four men were at one tube raking the dust out with long rakes when three of them were "gassed." Two of them died shortly afterwards, and the third died on Monday. It seems that one of the men who was not used to the work entered the pipe unknown to the other men, who had gone for a new rake. When they found he lay helpless in the pipe they went to his rescue, and were in turn overcome. They were eventually all brought out and artificial respiration was tried and oxygen applied, but without avail.

THE EDUCATION OF THE FOUNDRY APPRENTICE.*

BY J. W. HORNE, B.SC. (EDIN.), A.INST.C.E.

IN the days when trade guilds were in existence (11th to the 16th century), the term "apprenticeship" signified not only practical training in a particular trade, but also training of character and intelligence, without which it is impossible to become a really efficient craftsman. In those days, during the period of apprenticeship a youth received such an education as trained him how to live, while at the same time fitting him to become an intelligent workman capable of earning sufficient to provide for the necessities of life. It is not the purpose of this paper to trace the changes which have taken place in the intervening centuries. Anyone who is interested in the subject will find considerable food for reflection in the contents of a book on the subject by Reginald A. Bray. He defines an apprenticeship system worthy of the name as having to satisfy three conditions:—

"(1) Adequate supervision for boys up to 18 years; supervision must take into account conduct and physical development.

"(2) Must offer opportunities of training both general and special; that is, the training of the citizen, and the training of the workman.

"(3) Provision of a suitable opening on completion of apprenticeship."

This system is ideal, and if ever considered is bound to lead to considerable controversy, but no one will deny that every effort should be put forward. No system of industrial education of the apprentice can be effective unless it gives him the capacity for becoming an intelligent workman, a healthy citizen, and a good neighbour. The main purpose of this paper is to awaken an interest in the training of foundry apprentices in this country, and to give in concentrated form some account of how the question is being tackled in other countries from which information can be obtained; to open up the whole question by discussion and to afford the members an opportunity of giving a definite lead to the Council of this Association as to what action should be taken in order that foundry apprentices may receive an industrial education fitting them to become not only intelligent moulders but also healthy citizens of the Empire.

The problem of the more efficient education of the engineering mechanic has during late years had the serious consideration of many industrial firms, with the result that considerable progress has been made. But so far as information can be obtained, no great development has taken place in improving the educational standard attained by the foundry apprentice, though the problem has not been neglected by foundry employers. Perhaps the main reason why development in their case is, and has been, so slow, is associated with the fact that as a trade moulding is generally held in low estimation. Though not the most mechanical of the trades, it must be remembered that a mould, to give a sound casting, requires more than the mere force necessary to ram the sand. There are a hundred and one things the moulder must know and consider. Moulders may have themselves to blame for this condition of affairs; in the first place, because there is only an inconsiderable number of them who have done, or are doing, anything to increase the esteem in which the public hold the trade, by increasing their respect for themselves; while in the second place, practically comparatively few moulders put themselves about to study the underlying principles involved in the moulders' art, or do anything to raise its status in the mechanical world. There can be no question that foundry work requires a considerable display of mechanical ability as well as a sound knowledge of the physical properties and composition of materials used. Whereas to-day in most industries machinery is taking the place of mechanical skill of the individual, this cannot be said of the foundry, as no great advance has been made in dispensing with hand moulding. Great mechanical ability is required to make a man a reliable and good moulder. To prove this to the world should be the aim of every moulder, commanding thereby increased respect for his trade. One effect of the low estimation in which the trade is held by other tradesmen and engineers in general has always been evident in the poor supply of apprentices with a standard of intelligence equal to that of those entering other trades, especially engineering. While the age of the apprentice entering as a fitter or turner has been raised almost generally to 16, with a resulting advantage, the starting age for the foundry is 14. This means that the boy starts handicapped with a less developed intelligence and at an age when factory life will have a greater deteriorating effect. No doubt much can be done by inducing these foundry boys to attend evening continuation classes; but the good derived from them can only be limited after a strenuous day in the shop. Perhaps there is no department in an engineering works in which apprentices can be kept so constantly employed.

The conclusions to be drawn from the above, with regard to lack of progress in intelligent and industrial education among foundry apprentices, is that it is due to the early age at which they leave school to enter an apprenticeship. Strenuous shop work and want of sufficiently developed intelligence at school prevents real progress at continuation classes. The first important duty, then, which would appear to devolve upon the Council and Members of this Association is to consider how best to raise the standard of the trade in the eyes of the public, so that the apprentices entering the foundry may be, as regards intelligence, equal to, if not better than those entering other trades.

In Germany great attention has been and is being paid to the industrial education of the foundry apprentice. Generally, the scheme follows on the lines laid down at the beginning of the paper. In its industrial life it is recognised that one of the most important requisites for the flourishing of an enterprise is a capable staff of workmen, the training of whom is one of the most important tasks of a manufacturing establishment, while at the same time it renders a social service to the country. Many of the large employers maintain apprentice schools within the factory, schools which are of an intellectual and not of a manual character. Apprentices therefore obtain a training in manual dexterity and skill under strictly apprenticeship conditions, along with intellectual work closely related to the shop work. The advantages of an employers' apprentice school are the saving of time going to and from school and the releasing of employers from the duty of supervising apprentices outside of shop hours. For those apprentices whose employers are unable to run an apprentice school, facilities on the same lines are provided by the municipalities. Ludwig, Loewe, & Co., of Berlin, were the pioneers in the formation of an apprentice school some 10 years ago. A short account of their scheme will be of considerable value and interest.

THE LUDWIG, LOEWE, & CO. APPRENTICESHIP SYSTEM.

Apprenticeship extends over a period of four years.

Practical Work.

MOULDERS.

Sand cores, nine months.
Loam cores, six months.
Sand moulding, twelve months.
Carpentry, three months.
Large sand moulding, seventeen months.
Testing and trimming, one month.

LOAM MOULDERS.

Loam cores, six months.
Carpentry, two months.
Small loam moulding, twelve months.
Large loam moulding, twenty-seven months.
Testing and trimming, one month.

School Work.

Two afternoons a week—one from two to six and the other from four to six, extending over the whole period of four years.

First Year.—General intelligence, two hours: The legal relations of the employers and employés; the rights and duties of working men; the history of Trade Guilds; the relationship of apprentices to the Guilds; accident and sickness insurances; Patent and Trade-mark law; citizenship; reading and correspondence. Drawing, two hours. (Instruction in this subject is specialised for foundry work.) Arithmetic, &c., two hours.

Second Year.—Workshop, two hours: Construction of a foundry; general arrangement; descriptions of the cupola,

* Paper read at the British Foundrymen's Association Annual Convention, Cardiff, August, 1912.

machines, &c.; lighting and heating; safety appliances; rules for the prevention of accident; hygiene; comradeship; courtesy, order and peace; payment of, and claim for, wages. Drawing, two hours. (Model drawing specially related to foundry work.) Arithmetic, two hours: Exercises in lighting and heating; transport of raw materials; costing.

Third Year.—Raw materials, two hours: Materials of construction; their production, classes, and properties; forging and rolling, &c.; properties and manufacture of copper, tin, zinc, &c., and their alloys. Arithmetic and geometry, two hours. Special reference to the foundry, and model drawing.

Fourth Year.—Foundry education: Description of the various foundry tools; moulding; casting; cupola practice, &c. Citizenship, one hour: Constitution of the State and Empire; Imperial revenues and expenditures; the rights and duties of citizens, &c. Drawing, two hours. (Special reference to foundry work.)

This short excerpt from the syllabus indicates that, while a considerable part of the time is occupied with work directly connected with the practical side of the foundry, the most important side of the education is the development of the true idea of citizenship and general intelligence.

The American Foundrymen's Association, a number of years ago, appointed a committee to handle the question of industrial education. The chairman of this committee is Mr. P. Kreuzpointner, with whom this movement is an earnest lifework. He reports that the National Government must come to the relief of the industries in the matter of industrial schools, since it is seen more and more that the industrial education of all the workers—and not only a few of the best ones—has become a necessity to preserve the industrial standing of the nation. The States of New York and Massachusetts have made a beginning—mention in the case of Cincinnati will be made later.

To make any plan of industrial education effective there must be earnest good-will and co-operation of educators, the manufacturers and business men, and the workmen themselves through their trade unions. This industrial education must be used not only as a means of imparting mechanical skill, but also to raise the ideals of citizenship and act as a socialising agency.

As an introduction to this paper, industrial intelligence was defined. It will be advisable here to expand it to the ideals of Mr. Kreuzpointner, who says:—

"The sum and substance of industrial intelligence, which should be one of the most valuable achievements of a broad industrial education, gives a man the power to see beyond the immediate performance of the operation at which he is engaged for the time being, the power to see the relation of his skill and the results of his work to the success or failure of himself and his fellow workmen; the power to see the intimate connection and interdependence between his careful or careless, his intelligent or unintelligent, honest or dishonest action, and his personal welfare, the welfare of those depending upon him, and the welfare of the community at large. Industrial intelligence includes some knowledge of materials; ideas of their production and cost; ideas of the organisation of a modern industry; ideas of the nature and extent of the business of the country, and a sense of duty and responsibility as a mechanic as well as a citizen. An education is of little value when rated only by a purely commercial standard."

Or, to quote the words of Mr. Thomas Burt: "I doubt whether the people of England have a sufficiently high conception of what education really means. The general idea of getting on is to make a fortune. That is a poor conception. Would they be willing to be millionaires if their intellect had to be dwarfed and their souls blighted?"

The foregoing quotation from Mr. Kreuzpointner's report goes to show that the Americans are going on the lines of Ludwig, Loewe, & Co. In an address to the National Education Association Convention, San Francisco, in 1911, Mr. Kreuzpointner pointed out the aims and tendencies of industrial education in Europe, referring specially to Germany, as the result probably of a visit to Dr. G. Kerschensteiner, superintendent of the schools of Munich, whose reorganised schools are justly attracting the attention of the industrial and educational world.

Mention has been made regarding the system which has lately been put into operation at the University of Cincinnati for the production of foundrymen. The system is, briefly, as follows:—

(1) Careful selection of high average quality of raw material by University and shop.

(2) Students work at the University and shop on alternate weeks.

(3) Students grouped in pairs; members alternate with each other in shop and University; both shop and classrooms are thus always manned.

(4) Student does same class of work as a regular apprentice, and under same shop discipline. If expelled from the shop, he ceases to be a student of the University.

(5) The student is paid for his work in the shops.

(6) A shops' schedule is arranged between the University and shop authorities, and in accordance with this a student is moved forward through the various departments of the shop.

(7) Students' school work is identical in standard with that given in all high-grade engineering schools. The shop instruction and certain laboratory courses, which would be but a duplication, or rather, a poor imitation of the experience the boys are getting in the shop, are omitted.

(8) The course is five years in length.

In the opinion of Mr. Porter, who has charge of this work, the most interesting and valuable feature of this course is the shop co-ordination work which has for its object the taking of the blinders off the boy, helping him to see the real meaning of the operations going on about him in the shops, and giving him an excellent benefit from shop experience; for example, if he has been on the cupola platform, the subject of pig iron may be taken up, while at another time, the theory of the cupola may be explained, and so on. An effort is also made to introduce the student to the best literature of the foundry. The great value of this feature of the work enables the student to better understand shop methods and processes, but it stimulates his interest in his work and helps to cultivate in him habits of observation. About a dozen of the leading foundries of Cincinnati and vicinity are giving their cordial co-operation to this scheme.

The Foundrymen's Association of France encourage the raising of the standard of foundrymen by offering money prizes for papers dealing with foundry problems; but no definite information can be obtained to show that the French education authorities or employers are doing anything to systematise the industrial education and production of foundrymen.

YELLOW BRASS MIXTURES.*

BY ERWIN S. SPERRY.

YELLOW brass mixtures are used in brass foundry work for two reasons:—

(1) They are cheaper than the red mixtures.

(2) They have a true brass colour.

The fact that the yellow brasses are cheaper than the red ones is responsible for their extensive use. While yellow brass is now extensively used for ornamental work, the cheapness is the main reason for its wide employment.

As a usual rule, brass founders do not like to cast yellow brass, and prefer to make composition castings. Go to a brass founder with a pattern to be cast in brass and ask him which he would recommend, and he will tell you in ninety-nine cases out of a hundred that composition is the best for your purpose. He knows that he can always obtain a good clean casting of composition, while with yellow brass he is apt to have dirty, drossy castings that will have a bad appearance. Yellow brass is much inferior to composition as a casting mixture, on account of the large amount of zinc it contains. The use of aluminium, however, has changed this condition somewhat and castings of yellow brass can now be made, by the addition of a little aluminium, which would never be attempted without it.

Use of Aluminium.—Aluminium has worked wonders in the making of yellow brass castings. Before its value was known, or before aluminium was anything but a curiosity, yellow brass was far less extensively used than at the present time on account of the difficulty of making clean castings. Even then the amount of zinc in the yellow brass mixture had to be kept as low as possible to avoid dirty castings.

* From "The Brass World."

Some classes of work could not be made at all and no brass founder would ever have thought of using as much zinc in yellow brass as can now be employed when a little aluminium is added.

The advantages of aluminium in yellow brass sand castings are as follows: —

(1) It removes the oxides from the metal and causes it to run free and fill all portions of the mould.

(2) It obviates the formation of pin-holes in the castings.

(3) It allows the castings to be poured flat on account of the greater fluidity of the brass when melted.

(4) It gives a good surface to the castings and the sand does not adhere to it.

(5) It allows a much greater amount of zinc to be used in the mixture, thus greatly cheapening it.

(6) It allows the brass to be poured at a much lower temperature and reduces the loss of zinc by volatilisation.

The amount of aluminium necessary for producing all these advantages is so small that it can scarcely be considered. It cannot be considered as an ingredient in the mixture and is really a deoxidising material. The amount of aluminium employed must be quite small, otherwise difficulty will arise in the way of shrinkage. The more aluminium is used, the greater the shrinkage of the brass castings, and nothing is to be gained by the use of a considerable quantity. A small quantity will do the work as well as a larger amount, and at the same time the shrinkage is less. With the amount ordinarily used, the shrinkage of the brass is not increased. The amount of aluminium to be used in making yellow brass castings (provided, of course, it can be used at all) is as follows: —

Yellow Brass	100lbs.
Aluminium	1oz.

This quantity, it will be appreciated, is very small, and even less can be employed. It can be added after the crucible has been skimmed and is ready to pour, or while it is in the fire. The amount of aluminium used is so very small that care must be taken to see that it actually enters the molten metal and is not left in the dross on the top.

Aluminium cannot be used for all kinds of yellow brass work, and for plumbers' brass goods, cocks, valves, gas-fixtures or similar work to stand pressure it cannot be employed. It causes them to leak under pressure. But for other classes of work, such as saddlery hardware, automobile castings and the ordinary run of yellow brass work it will be found invaluable. To be sure it produces dirty castings if the brass is poured too hot, but with care and judgment, more good castings can be obtained with aluminium than without it. When a casting with aluminium in it is good, it cannot be equalled, and the dirt or dross is usually on the outside where it can be readily seen and the castings rejected. The castings will run sharp and true and a greater number of pieces can be put upon a gate. If aluminium is not used in the yellow brass mixture, it will usually be found that the mould will have to be poured on end with the clamps on it, or after a manner practised before the advent of aluminium. When a little aluminium is used in the brass, however, the work may be poured flat and without forcing into the mould or pouring it smoking hot.

When to use aluminium and when to avoid it will have to rest with the brass moulder, but it should be borne in mind that it should never be used in work to stand pressure, even though it be light.

Use of Lead.—The majority of yellow brass castings have some machine work done upon them, or are polished and buffed. For this reason, it is necessary to use lead in the yellow brass and there are very few brass castings now made which do not contain it. In fact, it is the exception rather than the rule. Lead also has another purpose in that it tends to make the brass run free and sharp and castings are less apt to leak under pressure when it is present.

The amount of lead used must be small, and much over 3 per cent. is not advisable or the castings will be weak and the lead is apt to "sweat" out or segregate. The amount of lead may be increased to 4 per cent. without doing much harm, but if allowed to go over this quantity trouble is apt to follow. With less than 3 per cent. of lead, the brass does not cut as freely as desired. It has been found by experiment that about 3 per cent. is right for ordinary work.

Gas Cocks and Fixtures.—One of the largest uses of yellow brass at the present time is the manufacture of gas-cocks and gas fixtures. The requirements of this class of work are as follows: —

(1) It must be as cheap as possible.

(2) It must have a suitable yellow brass colour.

(3) It must cut freely.

Too much zinc cannot be used in the mixture or it will have a reddish shade that is undesirable. The colour must be that of yellow brass. As the work is done upon automatic machinery, the brass must cut well. The following is the mixture extensively employed for this class of work:

Gas Cock Mixtures.

Copper	66lbs.	or 660 grams.
Zinc	31lbs.	or 310 grams.
Lead	3lbs.	or 30 grams.
Total	100lbs.	or 1,000 grams.

Aluminium should not be used in this mixture.

Fine Ornamental Castings.—While the great proportion of art metal work is cast in bronze, as this is suited for the work far better than yellow brass, it is frequently necessary to make high-grade yellow brass castings for art work and a suitable mixture is necessary. The cost of the mixture in such a case is of no importance, and casting qualities are of more account than anything else. The following mixtures will be found very suitable for the highest grade of work: —

Mixture for Fine Ornamental Castings.

Copper	75lbs.	or 750 grams.
Zinc	22lbs.	or 220 grams.
Tin	2lbs.	or 20 grams.
Lead	1lb.	or 10 grams.
Total	100lbs.	or 1,000 grams.

In the preceding mixture for ornamental brass castings, the tin is necessary to strengthen and harden the metal. So little zinc is used that the mixture is quite soft without it. If, however, a soft mixture is desired, then 1lb. of tin instead of 2lbs. may be used. The little lead is used to allow chasing, cutting, and polishing to be done on the brass readily, but there is not enough to cause trouble in casting or in dipping. The colour of the mixture is greenish-yellow and this is really the most pleasing of all the brass-mixtures.

Aluminium should not be used in this mixture as it is unnecessary. There is so little zinc in the mixture that no difficulty will be experienced in casting it.

Ordinary Ornamental Castings.—For ordinary work of an ornamental nature, it is unnecessary to use as expensive a mixture as the preceding one and the following may be employed: —

Mixture for Ordinary Ornamental Castings.

Copper	66lbs.	or 660 grams.
Zinc	33lbs.	or 330 grams.
Lead	1lb.	or 10 grams.

The lead is kept low in the mixture in order to produce a good dipping brass. Most ornamental castings are dipped in an acid dip to brighten them, and if much lead is present it causes trouble and it is impossible to obtain a bright surface on them. A little lead is desirable, however, as it allows machine work and polishing to be done without difficulty.

Aluminium can be used in this mixture if desired, but as a usual rule it is unnecessary, particularly if the work is quite small and is poured "on end." Large work can be cast with aluminium in the mixture, and the brass founder can readily determine when it is best to use it. Aluminium does not affect the dipping qualities of the brass.

Enquiry into Mine Fires.—The Home Secretary has appointed a Committee to enquire into the circumstances in which spontaneous combustion of coal occurs in mines, its causes, and the means of preventing it or of dealing with it when it has arisen. The Committee consists of Mr. R. A. S. Redmayne (chief inspector of mines), chairman, Sir Arthur Markham, Mr. C. E. Rhodes, Mr. Frank Rigby, and Mr. Herbert Smith.

THE UTILISATION OF PEAT FOR POWER PURPOSES.*

BY MR. H. V. PEGG.

THE question of the utilisation of peat fuel for power purposes has received a large amount of attention from engineers for many years past. Efforts in this direction have mostly taken the shape of some form of preparation of peat fuel in order primarily to get rid of the superabundant moisture in the fuel. Very large sums of money have been spent on peat-preparing machinery with generally very inadequate results; hence it has always appeared to the author that, in order to bring the utilisation of peat to a commercial level, the first consideration would be the utilisation of the peat as far as possible in the condition in which it leaves the boglands without any preliminary and expensive machine treatment.

The author had the opportunity about seven years ago of experimenting with air-dried hand-cut peat fired into a special form of gas producer. With all gas producers using bituminous fuel, the main trouble is to get rid of the tarry by-product. In this instance the gas producer was arranged to work intermittently, there being periods of "blowing" during which the fuel in the producer was urged to incandescence, and periods of gas making during which the tarry by-products were passed through the incandescent fuel where they were split up into gas. The chief difficulty experienced with this plant was the high thermal value of the gas generated, about 330 B.Th.U. Owing to the high and varying percentage of hydrogen in the gas, it proved unsuitable for use in the works gas engine; and although the plant was running more or less continuously for 10 days driving the whole works, very considerable trouble was experienced, not only in the engine, but also in the plant, owing to the varying moisture content of the peat, the producer plant being decidedly sensitive in regard to this latter point.

From the experience then gained it appeared evident that it would be wiser to extract the tar from the gas rather than to try to utilise the same by converting it into gas, and, further, that the producer must be comparatively non-sensitive to the amount of moisture in the peat fuel. Some two years ago the author discussed the question of the utilisation of air-dried peat fuel with Mr. Hamilton Robb, of Portadown, who, having large supplies of such fuel convenient to his factory at Portadown, was strongly of opinion that it should be possible to utilise such fuel in order to generate the power required in the factory. As the result of various tests run with experimental plant at the works of Messrs. Crossley Brothers, Openshaw, a special plant was eventually manufactured by them under their designs and patents and to the author's specification. This plant, which has been running since last September, has been so often dealt with in the daily and technical Press that there is no need for the author to dwell upon the details of the plant, but he proposes to make a few remarks in regard to the difficulties experienced.

Air-dried peat is not a very convenient fuel to fire into the producer, and as it was uncertain whether it would be possible to burn the fuel direct in the form in which it came from the boglands, provision was originally made in the plant to deal with peat fuel prepared by being reduced in size to blocks of about 5in. cube, but it was found possible to dispense with the preliminary treatment, and the construction of the plant was thereby considerably simplified.

As regards the general running of the plant, last October it was subjected to a test run of six hours' duration with a load of 250 b.h.p., the peat consumption per brake horse-power averaging 2·55lbs., the peat fuel containing 18·98 per cent. of water; this was with both producers running, although the load was considerably below the total capacity of the plant. When necessary, it has been found that the above load can be safely carried with either producer working singly, and the plant has run under these conditions for several days.

It will be noted that the percentage of moisture in the fuel during the above test was unusually low. This was owing to the unusually dry summer of 1911. During November and especially December last the fuel fed to the plant was extremely wet, as the rainfall in those months was very heavy and the fuel supply was, and is, entirely exposed to the weather. The plant, however, worked just as well with sodden peat as it did with the drier peat, the only difference being the amount of fuel consumed. The amount of water in this "sodden peat" varied considerably from day to day, and the exact percentage was not arrived at; as near as could be estimated, it was at least 70 per cent.

The separation of the tar from the gas was the chief difficulty to be overcome; it was found far better to rely on an ample water spray through which the gas passed rather than any form of a coke scrubber, as the coke rapidly became clogged with tar. The main portion of the tar was thrown out into a tar sump by a centrifugal tar extractor; but unless the gases were subjected to a thorough washing and cooling by the water spray above referred to, it was found that a certain proportion of tar got past the extractor, collected in the gas mains, and finally found its way into the gas engines. It was a matter of experiment as to the precise amount of water sprayed into the cooler which was necessary in order to ensure that the tar vapour should be sufficiently condensed before reaching the centrifugal extractor, so as to enable the extractor to effect the needful separation. As now arranged, the proportion of tar in the gas after passing the extractor is small, and the engine valves do not want cleaning out more than once a week.

When first started, the plant generally, and especially the producers, required a thorough cleaning once a week; at the present date the plant can be run if necessary for three weeks without cleaning, though the weekly cleaning generally takes place as a matter of policy. This result has been obtained owing to the increased amount of washing water used, which now amounts to about 7 gallons per brake horse-power per hour. The proportion of tar recovered is about 5 per cent. of the weight of fuel consumed, and during the initial stages of the running of the plant a certain amount of this tar was sold to tar-felt manufacturers at a price of 35s. per ton, but sales in this direction ceased owing to an, at present, ineradicable pyroligneous odour which persistently clings, not only to the tar itself, but to all the various oils distilled therefrom.

Experiments have also been made with the tar in oil-burning boilers, but owing to the very high percentage of water in the tar —up to 50 per cent.—and the large quantity of solid matter also present, a very large amount of preliminary treatment is necessary. For a considerable period the tar at Portadown was used mixed with coal and burnt under a Stirling boiler; the precise heating value of the tar so consumed has not, however, been ascertained. At the present time the whole factory at Portadown is run entirely on peat fuel, the consumption being about 44 tons per week, of which the producer plant takes about 22 tons. The nature of the peat varies considerably; with good black heavy peat the weekly consumption for all purposes drops as low as 35 tons; and with light top peat from the surface of the boglands the consumption rises to 54 tons. It is also interesting to note that the quality of the peat is reflected in the carrying capacity of the barges which bring a load of 35 tons with heavy peat and 24 tons light peat. The peat is unloaded from the barges and conveyed to the producer platform and boiler house by a transporter. Clinker troubles are not often experienced, and only when burning the inferior grade of peat, the presence of sand in the fuel causing the trouble.

The author is indebted to Mr. W. A. Mullen, manager at the factory of Messrs. Hamilton Robb, Ltd., for the following figures in regard to the cost of fuel, these figures being given on June 12th last:—

Cost of running Factory on Coal, per week—

	£	s.	d.
8½ tons of Anthracite at 35s.	14	17	6
19 tons of Steam Coal at 17s.	16	3	0
	£31	0	6

Cost of running Factory on Peat, per week—

	£	s.	d.
Say up to 50 tons of Peat at 6s.	15	0	0
Weekly saving..................	£16	0	6

Allowing for 15s. for extra labour, the net weekly saving figures out at £15. 5s. 6d.

The author would here refer to the letter in "Engineering" of January 26th last, in which the general manager of the Power Gas Corporation, Ltd., gives some very interesting particulars in

* Paper read at the Belfast meeting of the Institution of Mechanical Engineers, July, 1912.

regard to peat plants, more especially an ammonia recovery plant working in the South of England. It would be of great interest if some figures as to the working costs of this plant could be laid before this meeting. It will be noted that plant is worked with ammonia recovery, which would mean a very much larger plant than that at Portadown. The amount of the nitrogen in the South of England peat is apparently high, and would appear to be considerably more than in the peat used at Portadown, analysis of which is appended hereto, together with analysis of the refuse tar and gas from the producer.

ANALYSIS OF TAR MADE BY MESSRS. TOTTON AND HAWTHORNE.

Sample of Tar No. 2.

The sample was grey when received, but very quickly turned black. On distillation it yielded :—

	Per cent.
(1) Water	37·2
(2) Light oils (distilling below 230° C.)	5·8
(3) Middle oils (distilling at 230°–270° C.)	8·3
(4) Heavy oils (distilling above 270° C.)	23·2
(5) Coke	17·8
(6) Loss	7·7
	100·0

Much frothing occurred until the water was distilled off. Towards the end the temperature went higher than a mercury thermometer will record (360° C.). The different fractions obtained were as follows :—

(1) Water faintly acid to litmus. Phenol could not be detected.

(2) Light oils (below 230° C.) became rapidly dark red in colour. Specific gravity of crude liquid 0·930.

(3) Middle oils (230°–270° C.) became dark red. Specific gravity of crude liquid 0·944.

(4) Heavy oils (above 270° C.) on standing, crystals of paraffin wax separated out to the extent of 5·42 per cent. of the fraction (=1·26 per cent. of the original tar). The specific gravity of the liquid portion of this fraction was 0·906.

ANALYSIS OF SAMPLE OF PEAT.

(Received on September 11th, from Mr. Hamilton Robb, Portadown.)

Proximate Analysis.

	Per cent.
Water	18·98
Volatile matter	55·17
Fixed carbon	24·75
Ash	1·10
	100·00

Ultimate Analysis.

	Per cent.
Carbon	44·60
Hydrogen	5·42
Nitrogen	0·97
Ash	1·10
Moisture	18·98
Oxygen (by difference)	28·93
	100·00

ANALYSIS OF AVERAGE SAMPLE OF GAS DURING A 10-HOURS' TRIAL.

Moisture in Fuel 26 per cent.

CO_2	10·6
CO	21·0
H_2	13·0
CH_4	3·7
Total combustible	37·7 per cent.
Calorific value (calculated from analysis)	144·0 B.Th.U.

Bulkheads and Boats on Ships: Board of Trade Enquiry.—The first official result of Lord Mersey's enquiry into the loss of the "Titanic" is represented by the appointment of a Board of Trade Departmental Committee to enquire into the whole question of boat-launching at sea. The difficulty of how to secure adequate boat accommodation is also to be taken in hand by the Board of Trade.

THE PRODUCTION OF THE "BRUSH-BRASS" FINISH.

THE "brush-brass" finish now so extensively used upon solid brass and brass-plated soft-metal goods is, says "The Brass World," a simple finish to produce, though many platers are apt to make hard work of it, and even with a large amount of labour are unable to obtain quite satisfactory results.

The method of producing the "brush-brass" finish is the same for plated or cast brass, although perhaps a little modification may be required for special patterns or designs. Strictly speaking, the finish is simply the production of innumerable fine scratches upon the surface, all running in the same direction. If these scratches are not uniform and some are deeper than others, then the effect is not good. If they do not run in the same direction the job will appear "botchy"; and if they are too coarse the effect is not satisfactory. The whole thing in a "nutshell," therefore, is to scratch the surface by any convenient means.

The production of the fine scatches upon the surface of the brass work may be accomplished in several different ways. One of the early methods was by the use of emery paste and a bristle or tampico wheel. This produces good results, to be sure, but it leaves the surface greasy, and cleaning is then necessary, which is apt to stain the surface to some extent. The grease in emery paste is hard to remove as it contains mineral oils, so that this method is not to be recommended unless absolutely necessary.

Another method is to use a rapidly revolving steel scratch brush, but this produces a satin-finish effect with a lustre that is undesirable. Various types of abrasives and wheels have been tried, but the most satisfactory method has been found to be the use of pumice ground to a suitable fineness and used wet upon a brass scratch-brush revolving slowly. The use of oil or grease in producing the finish is not to be recommended, as it necessitates subsequent cleaning with its extra cost and dangers of abrading or staining the surface.

The grade of ground pumice to be used will depend upon the character of the work. Some manufacturers prefer a finish that is quite "scratchy" while others desire one that shows the scratches to a very slight effect. The different effects can readily be obtained by varying the grade of pumice. The grade ordinarily used, however, for the production of a good "brush-brass" finish is No. ·0½.

In producing a satisfactory "brush-brass" finish, the first thing to do is to obtain a surface on the article. The matter is exactly the same as though the article is to be buffed to a high "colour." Every plater knows that it is useless to buff a piece of brass until all the scratches, dents, and pits have been taken out. In other words, the brass must be surfaced at least, and brought almost to a "colour." The object is to obtain a base for producing the "brush-brass" finish, so that there will be no scratches in it deeper than those desired. This instruction, however, applies only to solid brass work, as plated work is usually ready for applying the finish after it has been plated.

When the brass has been surfaced and brought to a condition that is free from scratches, the "brush-brass" finish may be applied. Use a small scratch-brush running rather slow, say about 300 revs. per minute. Apply the pumice and water to the wheel, and hold the work against the wheel until the desired effect has been produced. The successful production of the finish lies partially in having the scratch marks run evenly and in the same direction. They should run lengthwise of the article, as a general rule, and the best effect will be obtained when such is the case.

When the article has been finished by the treatment with the pumice and scratch-brush, it is ready for lacquering. The fact that nothing but water (and no oil or grease) has been used, renders it easy to lacquer the article. All that is necessary to do is to wash it off, dry, and lacquer in the regular manner. If, however, a large number of pieces are carried through at a time, considerable time may elapse before the lacquering can be done; and when such is the case, it frequently happens that the surface becomes stained or slightly tarnished before it can be lacquered. This can usually be removed by a muriatic acid dip, or if not by a cyanide dip. The muriatic acid is to be recommended, as it does not cause spotting-out, while cyanide

frequently will. The muriatic acid will usually remove any slight stain. Use the following:—

Water .... 2 gallons
Muriatic acid .... 1 gallon

If, however, this does not remove the stain, then use 1lb. of cyanide dissolved in 1 gallon of water. This, however, is more apt to cause spotting out by entering the pores or joints of the article and afterwards working out. For this reason the muriatic acid is to be preferred whenever it is possible to use it.

Care must be used in rinsing and drying the article after finishing to avoid abrasion or staining. Then apply a coat of suitable lacquer. Lacquer manufacturers now make a special grade of lacquer for this class of work, and when used it will produce the best effect. The use of a lacquer not adapted for the work may ruin what is otherwise a good job.

SMOKE ABATEMENT EXHIBITION AT GLASGOW.

A second smoke abatement exhibition organised by the Corporation of Glasgow will be held at Glasgow from Friday, September 20th, till Saturday, October 12th. The main features will be similar to those of two years ago, but the display of appliances will be more varied and will make a wider and more general appeal. The purpose of the exhibition is to bring in a practical and interesting fashion to the notice of the citizens the most scientific devices in connection with smokeless heating and lighting, embracing every up-to-date method and contrivance for the complete combustion of solid fuel, and also the most modern developments in heating, cooking, lighting, and ventilation by means of gas and electricity for domestic, business, and manufacturing purposes. The exhibition, as has been stated, is organised by the Corporation and under the auspices of the British Electrical and Allied Manufacturers' Association, the Coal Smoke Abatement Society, the Smoke Abatement League of Great Britain, and the Glasgow and West of Scotland Branch of the Smoke Abatement League. Arrangements have been made for lectures which will be given daily on subjects applicable to the aims and objects of the exhibition, and these along with a series of demonstrations and competitions, promise to be popular features. The processes which will be demonstrated include paper-bag cookery, sweet making, sick-room cooking, bread making, cooking, baking, fancy bread making, boiler furnace firing, and stoking. Efforts will be directed to giving the exhibition publicity beyond Glasgow, and the Corporation will, it is expected, invite a large number of representatives of public bodies throughout Great Britain to pay visits.

Journal of the Municipal School of Technology, Manchester.—The fifth annual volume of the Journal of the Municipal School of Technology, Manchester, just issued, is more than usually interesting. As a record of investigations undertaken or published by members of the teaching staff and students of the school during the past year, it covers, naturally, a wide range of subjects, but several of them are of special interest to engineers. The most lengthy of them is a reproduction of a paper read by Prof. J. T. Nicolson before the Institution of Shipbuilders of Scotland on the effect of high velocity of flue gases on boiler economy, a subject to which Dr. Nicolson has paid a great deal of attention, and the pros and cons of which, from a commercial point of view, have been much discussed. Two other contributions are also particularly interesting at the present time in view of the attention being paid to the question of power transmission in textile mills, one by T. M. Ritchie "on the application of a fly-wheel to a mule countershaft," and the other by J. Gorton, "on testing of power consumed in driving looms." A third paper, by W. Meyers, "on the examination and testing of cloth," deals very exhaustively with a subject which should be of special interest to textile men. These do not by any means exhaust the range of matters dealt with, and which roam over the electrical, metallurgical, and physical fields, and furnish evidence of the high attainments of the teaching staff of what easily ranks as the first technological school in this country

HOT WEATHER TRAIN DERAILMENT AND ITS LESSONS.

The official report by Major Pringle on the derailment of a train which occurred between Whitstable and Faversham on the 22nd June last, attributes the accident to "rail creeping," as a consequence of excessive heat and the lack of adequate expansion spaces, as evidenced by the fact that when replacing the road it was found necessary to shorten a pair of rails by 4½in. The report says: It is unlikely that any noticeable horizontal deformation of the road had taken place before the train reached this spot, but the rails must have been in a high state of compression: possibly some vertical deformation or humping of the track had actually taken place. The movement or weight of the engine would be sufficient, especially with light and insufficient top ballast, to "spring" the track out of line. The deformation would be increased by the following vehicles. The irregularities in line, which the bogies of the last four coaches faithfully followed, at the cost of bufferlocking, were too great for the 6-wheeled brake van in the rear, with a wheel-base of 19½ft. to negotiate, and the derailment of the vehicle resulted. The accident, it is added, affords a good illustration of the greater freedom from liability to derailment of bogie vehicles, when compared with six-wheeled vehicles, and strengthens also the contention that the best position for six-wheeled stock, when it is found necessary to marshal them with bogie stock in an express train, is at the end of the train.

INDUSTRIAL AND TRADE NOTES.

The "Titanic" Enquiry.— The total cost of the "Titanic" enquiry will probably be considerably over £40,000.

Sherardising. — This process, we are informed, is making rapid progress in the United States, where there are some 31 plants at work, and is being extensively used by the General Electric Company for line material. A committee of the Franklin Institute of the State of Pennsylvania have recently made a report on the process, and have awarded the inventor, Mr. Cowper Coles, the John Scott Legacy medal and premium.

Clyde Shipbuilding for July.—The Clyde shipbuilding output during July is large, the total of over 40,000 tons having been only three times previously exceeded. As compared with the corresponding months of last year there is an increase of 6,000 tons. The total of 330,000 tons falls short of the corresponding total of last year by fully 10,000 tons. Very little new work has been placed during the month, and orders are expected to be fewer, in view of the increasing cost of production.

Copper Production in Japan.—The Belgian Consul at Yokohama reports that the total production of copper in Japan in 1911 amounted to 51,708 tons, valued at 26,938,000 yen (yen=2s. 0½d.), being an increase of 2,562 tons in quantity and 1,119,000 yen in value over the production in 1910, and an increase of 13,734 tons as compared with 1909. More than half the copper is got from the three principal mines, viz., Ashio, Besshi, and Kosaka. The Hidate mine is also making great progress, and turned out 5,674 tons last year, or more than seven times the quantity turned out by this mine in 1907.

Wages in the Midland Iron Trade.—The report of the Midland Iron and Steel Wages Board, the body which controls these industries in Staffordshire, Worcestershire, Shropshire, South Wales, Lancashire, and Yorkshire, shows the total output of 17 selected firms for May and June to be 43,500 tons, an increase of no less than 22,000 tons over the preceding two months. The average net selling price of £7. 4s. 9d. represents an advance of 4s. 4d. per ton. Under the sliding scale puddlers' wages are advanced by 3d. to 9s. 6d. per ton from August. When the extra bonus of 6d., recently agreed to, comes into force, they will receive 10s. per ton.

Steel Trust Earnings. — The statement of earnings of the United States Steel Corporation for the quarter ended June 30th is as follows: Earnings during month of April $7,509,000, during May $8,847,000, during June $8,746,000. Total earnings after deducting all expenses incident to operations, $25,102,000; net earnings for quarter, $18,429,000; surplus net increase for the quarter, $12,715,000. The dividends on the common and preferred stocks continue unchanged, being respectively 1¼ and 1¾ per cent. Balance of surplus for the quarter, $56,000. The figures for the quarter ended March are as follows: Total earnings, $17,827,000; net earnings, $12,108,000.

Prosperity of the Uganda Railway.—To those who opposed the construction of the Uganda railway scheme its present prosperous state must be disconcerting. It was declared to be a waste of public money. Pessimists predicted that 13 millions would eventually find its way to the scrap heap. Yet we are now told that the working of the line is producing a profit of £135,000 a year, and the expenditure of further sums is asked for to increase its efficiency. Cotton, tobacco, rubber, and wool are all named amongst the products exported, and the time is probably not distant when every trace of debt will be wiped off and a goodly profit finds its way to the British exchequer.

A Circular File.—A new form of file in the shape of a circular disc with a series of annuli with file teeth the slope of which inclines in opposite directions in any two adjacent annuli has been put on the market by the Haye's File Company, of Detroit, Michigan. It is intended for filing solder, aluminium, Babbitt, and other soft metals. The disc when used is mounted like an emery wheel, but is revolved at a much slower speed. About 200 revs. per minute are employed for a disc 14in. diam. The file, it is said, does not clog on account of the manner in which the teeth are cut and the tool should find a frequent use in brass foundries and other establishments for filing soft metals and upon work that has previously been done by hand.

A Diesel Oil Engine Ship.—A preliminary trial trip was carried out last week of the Diesel oil engine ship "Eavestone," owned by Messrs. Furness, Withy, & Co., Ltd. The engine with which she is fitted has been supplied by Messrs. Richardsons, Westgarth, and Co., of Middlesbrough, under joint license from Messrs. Carels Frères, of Ghent, and the Diesel Engine Company, Ltd., of London. The engine has four cylinders, each 20in. diam. by 36in. stroke, and at 115 revs. per minute develops over 850 b.h.p. The vessel has a single screw and is 276ft. in length by 40ft. 6in. in beam, with a dead-weight capacity of about 3,600 tons and displacement of 4,400 tons. As compared with a sister ship driven by steam engines, the extra space available for cargo on a 30 days' trip amounts, it is stated, to 400 tons.

All-Ceylon Agricultural Exhibition.—Messrs. David Bridge & Co., rubber machinists, have attained several successes at this exhibition during the past month with their improved preparation machinery, viz.: Cup and gold medal for thick blanket fine amber crepe, being the best rubber in the show, awarded to the Pambagama Estate; silver medal for scrap rubber in crepe form awarded to the Talagalla Estate; silver medal for crepe rubber to the Troy Estate. All the foregoing rubber was made in Messrs. David Bridge & Co.'s mills. Independent of the above awards, they were awarded two diplomas de Grands Prix, Brussels International Exhibition, 1910, for rubber preparation machinery and driving mechanism in addition to awards at the Coomassie Agricultural Show and at the Mexican Exhibition, Crystal Palace, in 1908.

Sirocco Induced Draught for Boilers.—Messrs. Davidson & Co., Ltd., Sirocco Engineering Works, Belfast, have issued an interesting and instructive pamphlet descriptive of the Sirocco system of induced draught for steam boilers. The pamphlet discusses the relative costs and advantages of induced and natural chimney draught and also describes a number of plants which the firm has installed on this system and the conveniences and economies that have been reaped in consequence. There are many cases where induced draught could be applied with great advantage, and the pamphlet is one which may be commended to the notice of steam users who are experiencing any of the many difficulties, such as smoke emission, inability to keep up steam pressure, &c., which spring out of lack of boiler power. Induced draught provides in many cases the cheapest and simplest way of getting out of these troubles.

Self-propelled Tramcars for London. — The Highways Committee of the London County Council, having given consideration to the question of the arrangements to be made for the working of the tramway from West India Docks to Cassland Road, Hackney, state that their attention has been directed to the arrangements in force in certain places for the working of vehicles by means of an internal combustion engine, directly coupled to an electric generator, driving through motors with electric control. The results of the working of this system as reported to them are such that they think it would be desirable to carry out an experiment with a view to determining whether it would be practicable to work this particular route by means of tramcars equipped in this manner. With this object they suggest that arrangements should be made for three of the existing horse cars to be altered and equipped for self propulsion at a cost of £2,100.

Coal Mines Act: Approved Schools and Authorities.—The Home Secretary has given notice that he has approved the following additional mining schools and authorities for the purpose of granting certificates to firemen, examiners, and deputies under the provisions of Section 15 (1) (b) of the Coal Mines Act, 1911: Birmingham University, Derbyshire Education Committee, Newcastle Education Committee, Rotherham Education Committee, Stoke on Trent Education Committee, Swansea Local Education Authority, Wrexham—Chester Street School, Carmarthenshire Education Committee. A complete list of the approved schools, institutions, and authorities will be found appended to the Home Office memorandum as to firemen's, &c., certificates. All applications for information as to the examinations to be held for the purpose of the grant of certificates should be addressed to the approved mining schools, institutions, and authorities, and not to the Home Office.

Trade Unions and Labour Agreements.—The Parliamentary Committee of the Trade Union Congress, at a meeting held at its offices, considered the question of labour disputes which is now being enquired into by the Industrial Commission. It adopted the following resolutions on the subject: "That this Parliamentary Committee hereby declares that any well considered plan to strengthen and bring into more general operation trade agreements duly ratified between recognised leaders of employers and workmen will be beneficial and reduce the number of irregular disputes." "In connection with the Transport Workers' dispute the committee expresses great regret at the breakdown of negotiations for the settlement of the dispute, and congratulates the men on refusing to surrender unconditionally. Whilst hoping that a resumption of negotiations may take place, the committee calls on all trade unionists throughout the country not to allow the men to be beaten for want of funds."

Cleveland Iron Workers' Wages.—The official ascertainment of production and prices in the Cleveland district for May and June shows that the output was 12,543 tons, and the net average selling price of rails, bars, plates, and angles £6. 13s. 0·84d. The production is the best for 18 months past, and although in the preceding two months the output was very small, due to the coal trade strike, the making up of arrears does not altogether account for this increase nor for the enhanced values realised. There has been a healthy genuine demand for finished iron, and prices have gone ahead in consequence. Compared with the corresponding months of last year the output is 3,700 tons better and the net selling price 7s. 6d. advance. Under the sliding scale arrangement there will be an advance of 3d. per ton on puddling and 2½ per cent. on all other forge and mill wages, to take effect from July 29th. This is the second advance this year, the previous one being made on the January and February ascertainment.

Admiralty Changes.—The Admiralty announces that the following appointments have been made and will take effect from August 1st, on the retirement of Sir Philip Watts from the office of director of naval construction, and of Sir William Edward Smith from that of superintendent of construction accounts and contract work viz.: As director of naval construction, Mr. E. H. Tennyson D'Eyncourt, naval architect to the firm of Messrs. Sir W. G. Armstrong, Whitworth, & Co., Ltd. As superintendent of construction accounts and contract work, Mr. William Henry Whiting, assistant director of naval construction. As assistant director of naval construction, Mr. William John Berry, chief constructor H.M. dockyard, Malta. Sir Philip Watts will be retained as adviser on naval construction to the Board. Mr. D'Eyncourt, the new director, has been a prominent official of Elswick shipyard for a good many years. He has a high reputation as a naval architect, and has had charge of very responsible work in warship building.

Suez Canal Traffic.—The navigation returns of the Suez Canal for the years 1909-11 show increasing prosperity. The number of vessels that passed through the canal in the years 1909, 1910, and 1911 respectively were 4,239, 4,533, and 4,969; their gross tonnage was 21,500,847, 23,054,901, and 25,417,853 tons; the net tonnage 15,407,527, 16,581,898, and 18,324,794 tons, and the transit receipts £4,777,927, £5,166,199, and £5,337,116. The net tonnage for last year showed an increase of 1,742,896 over 1910. This effected an increase in the gross receipts which in 1911 amounted to the highest sum ever reached. The number of British ships which passed through the canal last year was 3,089, as compared with 2,778 in 1910 and 2,561 in the year before. British tonnage increased from 10,423,610 in 1910 to 11,715,947 last year, and German from 2,563,749 to 2,790,963 tons. The percentage of British vessels and their net tonnage increase in 1911 in comparison with 1910, being 62·2 and 64 respectively, as against 61·3 and 62·9 in 1910 and 60·4 and 62·3 in 1909.

Commercial Intelligence Branch of the Board of Trade.—The Commercial Intelligence Branch of the Board of Trade desires to point out to British manufacturers and merchants who may wish to obtain information in regard to trade matters, including the names of importers and of possible agents, in foreign countries, that it is desirable that application should first be made to the Commercial Intelligence Branch, 73, Basinghall Street, London, E.C. before communications are addressed to H.M. Consular officers abroad. By the adoption of this course much delay would be

avoided by the enquirer in those cases in which the Intelligence Branch is already in possession of the required information. Particular attention is drawn to the advisability, when communicating with British Consular officers, of addressing such officers by their official designations and not by their names, in order to avoid possible delay. The adoption of the latter course is liable to involve considerable inconvenience and delay to enquirers, owing to possible changes in the Consular staff.

Royal Commission on Oil Fuel.—The King has been pleased to approve of the appointment of a Royal Commission to investigate and report on the supply of oil fuel for the Navy. The terms of reference are as follows: "To report on the means of supply and storage of liquid fuel in peace and war, and its application to warship engines, whether indirectly or by internal combustion." The following will be members of the Commission: Admiral of the Fleet the Lord Fisher of Kilverstone, G.C.B., C.M.G., G.C.V.O. (chairman); the Right Hon. George Lambert, M.P.; Sir Boverton Redwood, Bart.; Sir Philip Watts, K.C.B., F.R.S.; Engineer Vice-Admiral Sir Henry John Oram, K.C.B., F.R.S.; Vice-Admiral Sir John Rushworth Jellicoe, K.C.B., K.C.V.O.; Sir William Matthews, K.C.M.G.; Sir Thomas Henry Holland, K.C.I.E., F.R.S.; Sir Thomas Edward Thorpe, C.B., F.R.S.; Alexander Craigie, M.V.O.; Humphrey Owen Jones, M.A.; Alfred Fernandez Yarrow. The following are the joint secretaries: Captain Philip Wylie Dumas, C.V.O., R.N.; Engineer-Lieutenant Charles John Hawkes R.N.; John Harper Narbeth, M.V.O., Royal Corps of Naval Constructors.

Criticism of Mines Regulations.—Severe criticism of the new Coal Mines (Regulations) Act was offered at the annual meeting at Newport of the South Wales and Monmouthshire Branch of the National Association of Colliery Managers. In his presidential address Mr. Jacob Ray, who has had a wide experience in some of the biggest pits in South Wales, dealt with the new rules in regard to pit ventilation. The new Act, he remarked, insisted that all ventilation should be reversible. Commenting on this, he said that in his mining experience cases had come to his knowledge where there had been found fire a week after an explosion, and had the air current been reversed the gas would have been brought back to the fire with terrible results. He would hesitate very much before taking the responsibility of reversing the air current. Yet it was the law. A number of delegates from various parts of the coalfield complained of the clause in the Act doing away with riders. Mr. John Evans said the complaints were bitter and general. Mr. Llewellyn, a colliery manager of Pontypool, said the night men in his district refused to work without a rider on the main road, and they were quite right.

Big Bridge Contract.—The largest bridge contract which has been placed in Great Britain since that for the Forth Bridge, has just been secured by British engineers, despite severe competition from Belgium, Germany, and American firms allied with the United States Steel Trust. The contract comprises the whole of the steel work required in the new railway and road bridge to carry the Eastern Bengal State Railway over the lower Ganges. The bridge, exclusive of approaches will consist of 15 main spans, each no less than 359 feet in length and 52 feet in depth at the centre, and weighing 1,300 tons each. The foundations for the masonry piers upon which the 15 spans will rest, are to be carried 150ft. below the bed of the Ganges, in order to guard against the deep scour of the river. The contract has been divided between Messrs. Braithwaite & Kirk, Ltd., of West Bromwich, who are to supply six of the spans, and the Cleveland Bridge and Engineering Company, Ltd., of Darlington, who have the order for the remaining nine spans, the first of which is to be shipped to the site before the end of the year. The work is being carried out to the designs of Sir Alexander Rendel, consulting engineer to the India Office, and, before completion the scheme will involve an expenditure of about one and a quarter million sterling.

The Werry Engine.—A 50ft. pinnace, to be attached to the cruiser "Australia," and driven by an engine invented by Mr. W. C. Werry, has been tried on the Thames. Both the engine and the pinnace have been built by the Thames Ironworks. The engine is of the compound type with the two cylinders placed horizontally between, and at right angles to, the twin shafts. The cylinders are double-ended and double-acting, and consequently they are provided with three inlets and three exhaust ports. They measure 5¼in. and 10½in. diam. respectively, with a 4in. stroke. The two shafts are coupled together by an intermediate shaft working on bevel gearing, with the object of keeping the two pistons of each cylinder in time, but this shaft also serves to drive the air and feed pumps. The steam pressure employed is 185lbs., and the speed of the engine is 1,000 revs. per minute. No actual figures of steam consumption are available; it is claimed, however, that the engine is economical as compared with the ordinary single piston cylinder and that the cost of construction is much less per horse-power. It is stated that plans have already been prepared for engines of 68,000 h.p., and that the principle can be adapted to internal-combustion engines.

The Commission on the Eight Hours Work Day.—The report has just be published on Saturday of the Special Commission appointed by the International Association for Labour Legislation to enquire into the hours of labour in continuous industries, and their report will be presented for consideration to the annual delegates' meeting of the association in Zurich next month. In trades working day and night the report states, the question of reasonable leisure is vital, since the 24 hours of each day are apt to be divided into two shifts of 12 hours, necessitating a spell of 24 hours work when the men change from the day to the night shift or vice versâ. The Commission claim to have proved that a reduction of hours can be economically profitable. Nevertheless, such is the fear of foreign competition, they state, that a general introduction of the eight hour day is unlikely without the backing of an international agreement, by which the same standard may be introduced simultaneously in all competing States. The Commission unhesitatingly condemns the prevailing system of 12-hour shifts, and definitely recommends the adoption of an international treaty to enforce the eight hour day in continuous industries, especially in the iron and steel trades. In cases where three eight-hour shifts are difficult to arrange for technical reasons, as in the glass industry, the Commission recommends that a corresponding maximum week should be enforced.

Egyptian Oil Fields.—The following information relative to the petroleum industries in Egypt is from the report by the British Pro-Consul at Suez, shortly to be issued. During 1911 the work of exploration in the Egyptian oil fields was pushed forward with energy. The one area which appears to have proved to be productive on a commercial scale is that comprising the peninsula of Jemsa. Nine wells have been completed in this area, most of them yielding oil of good quality, and in quantities highly satisfactory; other wells are being sunk, tanks of large capacity are being erected, and all preparations made to market the crude product at any early date. Exploratory work is in progress at Zeitia, by a company which has also carried on work by means of borings at Ras Bahar to the north of Jemsa, Ras Dhib, and on Gaysoon Island. Another company has continued its work on the Island of Jubal, around the north end of which strong evidences of oil occur in the sea. Encouraging indications have also been met with from time to time during boring operations on the island. On the mainland to the south of Jemsa some work has been done whilst on the opposite side of the Gulf of Suez, on the coast of Sinai, indications of oil have been met with in borings at Abu Zenima. Meanwhile the work of prospecting is being carried further afield, and at an early date further development will probably be undertaken.

Automatic Telephones.—The Automatic Telephone Manufacturing Company, of Liverpool, gave a demonstration in the General Post-office, St. Martin's-le-Grand, of an automatic telephone exchange which they have recently fitted up there. The exchange, which is on the Strowger system, has been in operation for some three weeks, and is being used for telephoning between the different departments as well as for communication outside. About 350 lines, involving over twice as many telephones are connected with the automatic exchange. The mode of operation briefly is as follows: Each telephone is provided with a small dial having 10 holes, numbered 1 to 10, near its circumference. When the subscriber wants to call up a certain number—say 435—he puts a finger in No. 4 hole and rotates the dial to the right as far as it will go. The dial, on being released, spins back to its original position, and in so doing sets the connectors and other apparatus of the telephone switchboard in motion for that number. The subscriber repeats the operation for 3 and then for 5. As soon as this is done the bell of subscriber 435 rings and the connection for speaking is complete. If the number is engaged the usual buzz is heard. A call can be made in four seconds. If this system comes into general use it will dispense with the services of an enormous number of telephone operators. It is stated that the system is largely employed in America, and that an installation for 6,800 lines has been ordered for Leeds.

New Russian Patents and Trade-marks Law.—The Board of Trade are in receipt, through the Foreign Office, of the text and translation of a law for the protection of patent rights and trade-marks, which has been recently approved by the two legislative chambers in Russia. The law provides that: Subjects of those foreign States which have concluded with Russia agreements respecting the mutual protection of industrial property on the principle of priority, who shall have applied in due form in one of these States for (*a*) a certificate to a trade-mark, shall enjoy for a period of four months from the date of such application a preferential right to receive for such trade-mark a specified certificate; (*b*) the grant of a patent for an invention or technical improvement, shall enjoy for a period of 12 months from the date of such application a

preferential right to receive the patent demanded; (c) the protection of an industrial design or model, shall enjoy for a period of four months from the date of such application preferential rights within which to complete notification of such design or model to the Department of Industry. Persons who are not subjects of foreign States which have concluded with Russia agreements respecting the mutual protection of industrial property on the principle of priority shall enjoy the privileges specified above only if this is specially provided for in the agreements aforesaid. In this case the above specified privileges will be applicable within the limits and on the conditions laid down by these agreements.

A Large Travelling Crane.—The Shaw Electric Crane Company, Muskegon, Mich., U.S., has installed in one of the shops of the Pennsylvania Railroad what is claimed to be the largest electric travelling crane ever built. The crane has a lifting capacity of 200 tons. It is fitted with two trolleys, each of which has handled a test load of 130 tons, making the total test load of the machine 260 tons. Each trolley is equipped with a 10-ton auxiliary hoist. The span of the crane is 74ft. 6in., and the lift 25ft. 4in. The speed of the main hoist, at full load, is 7½ft. per minute; of the trolley, 100ft. per minute, and of the bridge 200ft. per minute. The full load speed of the auxiliary hoist is 22ft. per minute. The crane is equipped with 3-phase, 60-cycle, 220 volts, General Electric motors. The motor sizes and speeds are as follows:—

	Hoist power, tons.	Revs. per min.
Main hoist	82	485
Auxiliary	22	650
Trolley traverse	22	650
Bridge	82	485

The bridge consists of two heavy box girders, each of which is mounted on a cast steel truck beam. Each beam has two wheels and the entire load is distributed on eight wheels. The two box girders are jointed near the top by a flexible steel member which ensures the distribution of the load equally on the eight wheels. These are double-flanged, steel-tyred, and 36in. diam. The depth of each girder at the centre is about 80in.

World's Railway Mileage.—The world's railway mileage in 1911, according to the annual compilation of the "Archiv fur Eisenbahnwesen," was as follows:—

Old World.		New World.	
Europe	207,488	North America	283,563
Asia	63,341	South America	43,638
Africa	22,905	Australasia	19,275
	293,734		346,424
The world	640,158		

The increase in the past decade was 119,092 miles, against 107,421 miles in the preceding decade, and 152,170 miles in the decade preceding that. In the eighties, it will be recalled, railway building in the United States was particularly heavy and this no doubt helped very largely to make the world's increase in that decade the record. Figures of this sort, while interesting and useful along certain lines, no longer serve to show the actual iron and steel consumption of the railways, their actual traffic, or their capacity. In the United States, for instance, the mileage of railroad has of late been increasing with relative slowness, but the actual traffic and the carrying capacity have been increasing quite rapidly. In the early days of railroading consumption of iron and steel was due chiefly to the building of new line. To-day it is chiefly due to two things: (1) Increasing the capacity of existing mileage by double-tracking, with some third and fourth tracking, and by adding to rolling stock, with such block signalling as is necessary to permit the increased density of traffic; (2) replacement of worn-out or obsolete material, due to rail and rolling stock replacement, replacement of bridges and viaducts by heavier structures, &c.

Liabilities in Engineering Contracts.—The judgment recently delivered by the House of Lords in the case of the British Westinghouse Company versus the Underground Electric Railways Company, London, is of great importance to engineers, as it seriously affects the question of guaranteed performances to which they are often parties in contracts for work. The chief facts which led up to the action in question are as follows: Several years ago the British Westinghouse Company supplied a number of large turbo-generators to the Lots Road Station of the Railway Company, which failed to comply with their guarantee, and after some time the Railway Company replaced them by machines of another design. These effected a great saving over those first installed, and the Railway Company claimed damages due to the inefficiency of the first machines and the cost of replacement. Their claim was laid before an arbitrator, and was upheld in the courts until the present judgment was reached. The House of Lords answers the questions of law stated by the arbitrator somewhat differently from the lower courts, and its judgment is substantially as follows: In addition to the facts outlined above it was admitted that in the interval between the installation of the first and second sets of machines the art of turbine manufacture had advanced so that it became a reasonable business proposal for the Railway Company to replace the early machines by more modern ones, even though the first machines had fully complied with the contract conditions. The House of Lords, therefore, concluded that the Railway Company should in any case have installed the second machines when they did, and that therefore the cost of such installation could not be charged against the British Westinghouse Company as suppliers of the first machines, but that they were bound to pay the damages incurred to the extent of the failure of their machines to fulfil the contract conditions during the period they were actually at work. Put into general terms, the Lord Chancellor stated that one damaged by a breach of a bargain to supply what he contracted to get was to be placed, as far as money could do it, in as good a situation as if the contract had been performed. The fundamental principle was compensation for pecuniary loss incurred by the breach; but this basic principle was qualified by a second, which imposed on a plaintiff the duty of taking all reasonable steps to mitigate the loss consequent on the breach, and debarred him from claiming any part of the damage which was due to his neglect to take such steps. In short, one cannot make money out of a breach of contract, but can only recover for unavoidable loss.

Shipbuilding and Engineering Apprentices.—On Thursday last week, at Carlisle, the Shipbuilding Employers' Federation met the Shipyard Standing Committee under the National Agreement to discuss the vexed question of the card system, introduced by the Boilermakers' Society for the purpose of organising their apprentices. In the year 1901 an agreement was drawn up and approved by the employers and the representatives of the Boilermakers' Society. By this means registration of apprentices at the various shipyards in the federated area was obtained. The agreement was for six years, after which there was to be six months' notice on either side to terminate it. The agreement remained undisturbed for nearly ten years, when the employers became dissatisfied with certain portions, and gave notice to end it. The document passed out of existence, we understand, in November of last year. Negotiations followed for an amended agreement, but delay arose in reference to age limitation, the employers desiring that riveters might commence an apprenticeship at any age from 16 to 25 years. The Society declined to entertain this proposal and in February last there being no agreement for ascertaining how many apprentices were coming into the trade, the Boilermakers' Society issued apprentice cards, and made arrangements for organising the apprentice iron workers into their union. A material fact in this propaganda was that for a weekly subscription of 3d. the apprentices were entitled to unemployment benefit. This was interpreted by the employers as a violation of the National Agreement, inasmuch as it might have an important effect should a dispute arise in any shipyard. The reply of the Society was that the organisation of the apprentices was a legitimate action on their part, and that it could not be construed as a movement other than of a pacific nature. It was asserted that the apprentices would work precisely as they had done in the past, but that, when they were unable to work because of a dispute of their own Society or of any other shipyard trade union they would receive unemployment benefit. This means that if the journeymen were idle because of some trouble, the apprentices would continue to work as long as jobs could be found for them, but, when they also came to a standstill in the yard, they would be entitled to the benefit alluded to. At the conference the Employers' Federation reiterated their objection to the card system, and urged its abolition. The feeling that it should be discontinued has prevailed all along, but some employers were inclined to be satisfied if the terms used on the cards were modified in such a way as to show that the movement is not inimical to their interests. The conference ended without any agreement being arrived at, and the matter, therefore, stands where it did when the employers framed their emphatic protest at Edinburgh in February. On that occasion the employers pointed out "that an apprentice is not to belong to any trade society, except for the purposes of benefit, nor is he to be interfered with in any way by any trade society." The Boilermakers' Society took up the position, it is stated, that the agreement was at that time out of operation, and that, therefore, it could not bear upon their action. On the other hand, the employers regarded the agreement as being observed while negotiations were in progress for an amended agreement. The matter is one between the employers and the Boilermakers' Society, and although the Standing Committee under the National Agreement were present they took part in the discussion. The machinery under the National Agreement is now exhausted, and it is not easy to see what the next development will be, though it is not likely it will be allowed to provoke serious trouble or disturb the present boom in shipbuilding.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Heat regulating devices for railway carriage and other steam heating apparatus. G. D. Peters & Co., and Le Clair. 1117.
Steam generator and other furnaces. Gregory, and Direct Gas Fuel, Ltd. 11508.
Casting machines. Soss. 13960.
Driving and stopping devices for high speed machines. Denne. 14164.
Slide operating mechanism for turret lathes. Potter. 14601.
Evaporating and concentrating apparatus. Dunn. 15990.
Reciprocating conveyers or screens. Norton. 16094.
Rotary piston pumps. Young. 16144.
Apparatus suitable for heating or cooling purposes. Marlow and Pulsometer Engineering Company. 16299.
Submarine signalling apparatus. Submarine Signal Company, and Evans. 16372.
Drilling or boring tools. Treglown & Noble. 16380.
Steam superheaters. Deane. 16424.
Coin-freed vending machines. Harris. 16526.
Steam superheaters for locomotives and other boilers. Robinson. 16686.
Apparatus for disconnecting tubes from headers of steam superheaters. Robinson. 16687.
Fluid-pressure engines. Mather & Platt, Ltd., and Chorlton. 16773 and 16780.
Production of wheels and similar disc-like bodies. Midland Railway Carriage and Wagon Company, and Curral. 16794.
Friction gearing. Dieterich. 17094.
Rotary fuel supports for gas producers. Koller. 17368.
Haulage clips for rope haulage railways. Blundell & Hemsley. 17458.
Automatic centrifugal clutches. Frank Wigglesworth & Co. 18597.
Valve for air and gas compressors. Titterton. 18973.
Safety-clutch mechanism for elevator or lift apparatus. Atkinson. 19209.
Braking apparatus for railway wagons. Clower & Marriott. 19596.
Safety apparatus for mining cages. Walton. 19933.
Controlling the air supply to natural draught furnaces. Grazebrook & Grazebrook. 20046.
Metal cutting, stamping, and drawing presses. Griffiths & Griffiths. 20064.
Valve mechanism for pneumatic tools. Allison. 20280.
Ignition devices for gas and oil engines. Newman. 20403.
Spark separator for locomotives. FitzHugh, Cunningham, and Reid. 20566.
Devices for consuming smoke and regulating draught in furnaces. Galli. 21339.
Steam separators or dryers. Verity. 21937.
Load extension indicator. Dalby. 22184.
Ash ejectors for ships. Trewent & Proctor. 22222.
Mechanical stokers. Wied & Vestesen. 22875.
Means for preventing the overheating of the exhaust valves of internal combustion engines. Ludlow. 24061.
Gear for the prevention of over-winding and controlling the speed of hauling engines. John Reginald Shaw. 24896.
Valve and valve gear for 4 stroke-cycle internal combustion engines. Sweetzer. 25291.
Starting device for internal-combustion engines. Menville and Menville. 25487.
Steam-engine valves. Morley. 25694.
Pistons for gas compressors. Mewes. 26116.
Valves. Tyler & Bidelman. 26586.
Centrifugal blowers. Baumann. 26618.
Hot water heating apparatus. Holladay. 27694.
Adjusting devices for rotary grinding machines. Ludwig, Loewe, and Co. 28018.
Riveting tools. Ruston, Procter, & Co., and Waddington. 28037.
Apparatus for the heating of water. Wilson. 28996.
Belt fasteners. Bristol. 29103.
Chucks for boring and drilling machines. Swinburne. 29349.

1912.

Driving chains. Hill, and Coventry Chain Company. 102.
Valve control and reversing mechanism. Kind. 187.
Automatic couplings for train pipes. Langlais. 2214.
Typographical line casting machines. Linotype and Machinery, Ltd. 2518.
Pumps. Robson & Swank. 2568.
Compressed air-distributing gear for pulsometers. Berning. 2853.
Boiler and other furnaces. Willis. 3306.
Wheel and axle bearings for road vehicles. Murray. 4813.
Packing rings for pistons and valves. Rankin. 4946.
Steaming device for bakers' ovens. Schick. 5969.
Steam generator furnaces. Kitchen, and Von Bernuth. 5989.
Two stroke cycle internal-combustion engines. Von Schmidt. 6273.
Smoke box doors of steam generators. Perkins & Taylor. 6349.
Rotary blowers. Green. 6686.
Apparatus for operating gas valves by variations of the gas pressure. Ehrich & Graetz (firm of). 7968.
Automatic car coupling devices. Woernley. 8584.
Valve gears of continuous combustion internal combustion engines. Sulzer. 9526.
Devices for arresting the motion of pit cages when the hauling rope breaks. Alcock. 9659.
Safety devices for lifts. Inman. 11580.
Turbo centrifugal pump units. G. & J. Weir, Ltd., and Petermoller. 13929.

ELECTRICAL, 1911.

Electric incandescent lamps. Deutsche Gasgluhlicht Akt. Ges. 3840.
Electric accumulator. Smith. 13758.
Electric lifts. Scott. 16532.
Electric switching devices. Hatfield. 17286.
Electric power transmission devices. Kleinschmidt. 18051.
Electrical ignition apparatus for internal combustion engines. Midgley & Vandervell. 21441.
Electric fuse. Hall. 22844.
Long tubular metallic filament electric lamps. Angold and Poynter. 24250.
Electrically operated valves for gas conduits. Thiem. 29140.

1912.

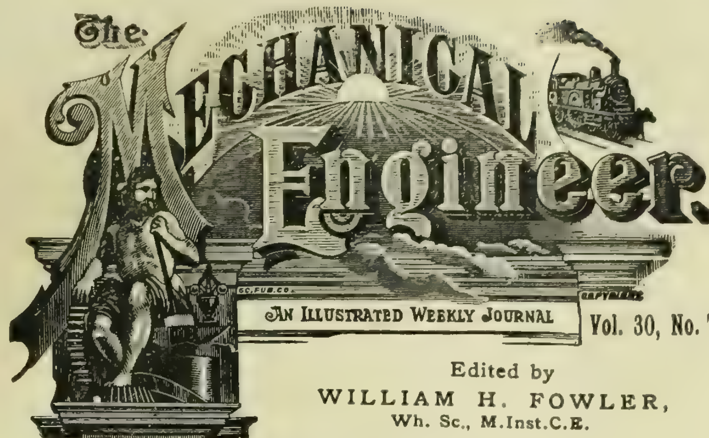
Manufacture of electric incandescent lamps. Deutsche Gasgluhlicht Akt. Ges. 874.
Cooling arrangement for dynamos. Siemens Bros. Dynamo Works, Ltd. 3106.
Electrical warp stop motions for looms. Schatz. 3114.
Apparatus for recording consumption of electrical energy. Gottschalk. 4791.
Press button electric switches. Wischhusen & Hepke. 7795.

METAL QUOTATIONS.

TUESDAY, AUGUST 6TH.

Aluminium ingot	80/- per cwt.
" wire, according to sizes, &c. ......from	102/- "
" sheets " " ...... "	120/- "
Antimony .... £28/-/- to	£28/10/- per ton.
Brass, rolled	8½d. per lb.
" tubes (brazed)	11½d. "
" " (solid drawn)	9¾d. "
" " wire	8⅝d. "
Copper, Standard	£78/5/- per ton.
Iron, Cleveland	59/10½ "
" Scotch	65/10½ "
Lead, English	£19/10/- "
" Foreign (soft)	£19/15/- "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£8/5/- per bottle
Silver	27⅝d. per oz.
Spelter	£26/-/- per ton.
Tin, block	£204/-/- "
Tin plates	14/7½ "
Zinc sheets (Silesian)	£29/5/- "
" (Stettin; Vieille Montagne)	£29/7/6 "

Lloyd's Register Scholarships Examination.—The examination for the Lloyd's Register Scholarhips of £50 per annum, tenable for two years, given under the auspices of the Institute of Marine Engineers, was held on July 8th and 9th, the examination centres being at London, Glasgow, and Newcastle-on-Tyne. Through the courtesy of the Committee of Lloyd's Register of Shipping two scholarships have been awarded this year, the successful candidates being Mr. Ian Garvie, Mansfield, Gourock (apprentice with Messrs. Scott & Co., Greenock), and Mr. Archie Allan, 22, Brislee Avenue, Tynemouth (apprentice with Messrs. R. & W. Hawthorn, Leslie, & Co., Ltd., St. Peter's Works, Newcastle-on-Tyne). Full particulars of these examinations, which are open to apprentice engineers, may be obtained from the Secretary, Institute of Marine Engineers, 58, Romford Road, Stratford, London, E.



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Edited by WILLIAM H. FOWLER, Wh. Sc., M.Inst.C.E.

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Tank Locomotives with Radial Axles.

Two Board of Trade reports that have been issued on railway accidents arising from train derailments raise again the question of safety of tank engines with radial axles. The accidents occurred within a few days of each other; one which occurred on the Dublin and South-eastern Railway was comparatively trivial, but the other, which occurred on the Lancashire and Yorkshire Railway at Hebden Bridge on June 15th, was particularly disastrous, four passengers being killed and 60 injured, in addition to the driver, fireman, and guard. In both cases the engines were of the 4-wheeled coupled tank type fitted with a leading and trailing pair of wheels, and in both accidents the derailment took place while going round a curve. In the case of the Irish accident the speed was low—probably not much in excess of 10 miles per hour—but there were facing points where the accident occurred and the curve was a sharp one, the radius being only 475ft., and to the combination of these two things with a slightly worn tyre Lieut.-Col. Donop attributes the derailment in question. In the report on the Hebden Bridge accident, Lieut.-Col. Druitt discusses the relationship between the type of engine and the risk of derailment more fully. It is not the first time it has been raised. Some years ago, in consequence of the frequency of derailments of tank engines, the Board of Trade requested the Associated Railway Companies to enquire into the behaviour of engines under different conditions of speed, but the enquiry did not lead to any very satisfactory result. The Associated Companies reporting in February, 1906, said "the derailments recorded by the Board of Trade during the previous 20 years were becoming fewer, and that there was nothing to indicate that there was any greater danger with a tank engine than with a tender engine, and they did not consider there could be any advantage in any further investigation of the matter at that time." The point, however, more particularly raised by the derailment in question is whether tank engines with leading and trailing axles are suitable for high-speed trains, and we think most engineers who

have studied the matter will agree with Col. Druitt they are not, and that a leading bogie is far preferable to a single swivelling pair of wheels. The danger of the latter is that the swivelling centre may by some unforeseen cause stick in its lateral guides and by so doing greatly increase the length of the wheel base. In the case under consideration, for instance, such a contingency would increase it from 8ft. 7in. to 16ft. 5½in., and though engines are built with this amount of fixed wheel base, it is admitted they are not suitable for high-speed passenger trains. Investigation did not reveal in the Hebden Bridge accident contributing circumstances in the shape of a worn tyre and sharp curvature, such as were disclosed on the Dublin line. The curve was a moderate one (1,980ft. radius), but on the other hand the speed was much greater, and though it cannot be stated precisely, it was probably over 50 miles per hour, and for this type of engine this was too high, even on a moderate curve, although it might be permissible with a bogie. The reasons that militate against a radial axle are too technical to enter into here, though they are well known and have been fully discussed by writers on the subject,* and it is to be trusted the Hebden Bridge accident will serve to impress its characteristic weakness on the minds of locomotive men, especially when high speeds and curves have to be negotiated.

Premium Bonus Systems in the States.

RIDICULOUS efforts to interfere with works' organisations are evidently not confined to this side the Atlantic, nor is the "premium bonus" system, of whose reputed merits so much was heard some two or three years ago, regarded in American shops with such unmixed approval as some of us were led to believe, judging from the text of a Bill which has recently been reported to the United States Senate. The avowed object of this extraordinary measure is "to regulate the method of directing the work of Government employés," and is apparently a consequence of the report of a Special Committee of the House of Representatives on the Taylor and other systems of management in Government workshops. That Committee took exception to any form of premium payment which depended for its working on time measurement, on the ground that the workman "considers such a procedure an indignity which recognises him as being a beast of burthen or a machine." This attitude of the ultra-trade unionist mind towards any approach to payment by results with which British employers have in many ways been made painfully familiar this last year or two is evidently spreading, for the means of repression proposed in this Bill should satisfy the most ardent cravings of the extreme Socialist. The text, as given by the "Iron Age," is as follows: —

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That it shall be unlawful for any officer, manager, superintendent, foreman, or other person having charge of the work of any employé of the United States Government to make or cause to be made with a stop watch or other time measuring device a time study of the movements between the starting and completion of any job of any such employé. No premium or bonus or cash reward shall be paid to any employé, except for suggestions resulting in improvement or economy in the operation of the plant in which he is employed."

The drastic penalties which would be inflicted if the Bill were to become law are quite in keeping with the cool presumption of the text, for section 2 would enact: —

"That any violations of the provisions of this Act shall be deemed a misdemeanour, and shall be punished by a fine of not more than $500 or by imprisonment of not more than six months, at the discretion of the court."

A strict interpretation of the above clauses, if they became law, would render it as illegal to make a time observation without the workman's knowledge as with it, even a glance at the shop clock at the beginning and end of a job would be fraught with risk. Indeed, it would require very little stretch to make the use of a shop clock illegal, or, in fact, to impose any restrictions on starting or stopping. By such easy legislative grades may we reach the millennium! It would be an insult to American common sense to suppose that such a preposterous proposal can pass over the counter, but that it should be put forward is evidence of the extent to which this kind of social poison has entered the minds of an ignorant section of American workmen, and suggests that the epidemic of labour troubles which it has created here is likely, before long, to break out on the other side of the Atlantic.

AUTO-ROLLING TANKS FOR SHIPS.

ONE of the greatest difficulties in the navy of accurate gun practice on warships is the rolling in bad weather, and a great deal of ingenuity has been devoted to reducing this trouble as much as possible. One of the methods employed has been to increase the spread of the bilge keels, but the extent to which this can be done is limited by the difficulties of docking, especially with the steady increase in width of ships, and on some of the later battleships and cruisers special auto-rolling tanks are being fitted. The idea is, of course, not new. Several German merchant liners and Cunarders have had them for several years. The principle is simply that of a mass of water contained in a tank of U shape in cross section. By contracting the water channel and by introducing an ingenious arrangement of baffle plates the motion of the tank water is deferred when the vessels tends to roll, and is in this way opposed to the action of the sea. In the battle cruiser "Tiger," now under construction, three of these tanks will be installed. The largest, just forward of the first boiler-room, will extend from the underside of the lower deck on the one side across the top of the inner bottom to the underside of the lower deck on the other side, and this tank will probably be subdivided by a bulkhead in order that one or both may be operated as required. The other two tanks will be situated in the way of the engine-rooms, and above the lower deck, rising at the sides to the underside of the upper deck.

Experiences with Steel Trolley Wire.—The use of steel trolley wire on electric railways is referred to in an article in a recent issue of the "Electric Railway Journal." Our contemporary states that it has not been employed for a sufficient length of time to determine its relative life and behaviour in service as compared with copper wire. The metal used is, in fact, not steel, but a very high-grade iron low in carbon and phosphorus and hence not subject to active corrosion. The tensile strength of a No. 0000 round steel wire is about 65,000lbs. per square inch, as compared with 59,000lbs. for hard-drawn copper wire. No difficulty has been experienced with steel wire in making splices or welds not exceeding ½in. in length and having a tensile strength of 80 per cent. of the wire on either side of the splice. The steel wire is easily coiled on reels, which are of slightly larger diameter than those used for copper wire, and it comes off the reel straight and true if it is not kinked in unwinding.

* See "Locomotive Practice" by C. E. Wolff. Scientific Publishing Company.

BOOK REVIEWS.

Boiler Explosions, Collapses, and Mishaps: Being a summary of the causes of boiler explosions, and recommendations for their prevention contained in the reports of the Board of Trade from 1882 to 1911, by E. J. Rimmer, B.Sc., Assoc.M.Inst.C.E., barrister-at-law, with an introduction by A. A. Hudson, K.C. London: Constable & Co.; 8½in. by 5½in.; 135 pp.; price 4s. 6d. net.

It is not easy to see where this book will find any large section of readers. It is not an engineering work except in the second-hand sense that it contains copious extracts from instructions which have been issued from time to time by the Chief Engineers of the various boiler inspecting and insuring companies, and those to whom such information might be of value will in the great majority of cases already have it by them first hand. Those who need legal information about their duties and responsibilities under the Boiler Explosions Act are, as a rule, indifferent until trouble overtakes them, and it is too late. A solicitor who has to work up evidence in defence of a careless or negligent client may find the book of assistance, and possibly it is him the author has mainly in view. He will no doubt find in the book a useful summary of the scope of the Act and of the consequences likely to spring from a neglect of it, and if he can, out of such knowledge, aid a client to evade the unpleasant results which a lynx-eyed Board of Trade Commissioner is likely to lay upon him, well, he will be clever.

* * *

Bulletin of the Charts of the Elements Metallic and Non-metallic. Second edition, 1912. Map form; 9in. by 6in.; unmounted in paper binding, 3s. 6d.; map form, mounted on linen to hang on wall, 8s. 6d.

The chart gives a descriptive bird's-eye view or map of every metal and non-metal which is known to exist, either combined or free, in nature, showing all the most important properties and constants which each possesses. Each metal or non-metal occupies a separate section, and these sections are arranged upon a new plan, based upon the "Periodic Law" of the Russian chemist, Mendeléeff. Thus, not only are the properties actually given available to the reader, but some idea may also be gleaned of the probable nature of the properties not yet known. The whole chart forms, therefore, a classification of the metals and non-metals which must prove useful to all classes of workers—from the pure scientist to the business man, and to everyone engaged in experiment or research of any kind, whether he be chemist, metallurgist, engineer, electrician, physicist, naturalist, manufacturer, or student of elementary chemistry. The chart is specially written for those not versed in chemistry and unacquainted with the periodic law of the elements, and it gives a concise explanation of the principles upon which the chart is founded, and a description of the methods by which it may be brought into practical use.

* * *

The Effects of Cold Weather upon Train Resistance and Tonnage Rating, by Edward C. Schmidt and F. W. Marquis. Bulletin No. 59 of the Engineering Experiment Station of the University of Illinois. London: Chapman & Hall, Ltd.; 24 pp.; price 1s. 8d.

Those concerned with train operation have always been aware that the resistance offered by railway trains is greater in cold weather than it is in ordinary summer temperatures. This bulletin presents the results of tests made to determine the amount of this increase in resistance. The tests show that even in moderately cold weather there is a very definite increase in train resistance over the resistance which prevails at air temperatures above 30° to 40°. This increased resistance is chiefly due to the lower temperatures of the car journals, and the bulletin indicates how slowly this journal temperature increases after the train is set in motion, so that in cold weather the train may have progressed 12 or 15 miles from its starting point before its resistance has reached its minimum value. The bulletin shows how great an influence these facts may have upon the rating of locomotives during cold weather, and it illustrates incidentally how the effect of heavy grades may operate to disguise the increased resistance due to air temperature. The bulletin presents also a summary of the practice of American railroads in reducing their ordinary tonnage ratings during cold weather.

BOOKS RECEIVED.

Iron and Steel Constructional Work. A concise handbook with examples for practical application. By Karl Schindler, translated from the German and adapted to English practice, by Chas. Salter. London: Scott, Greenwood, & Son. 7¼in. by 4¾in., 136 pp. Price 3s. 6d. net.

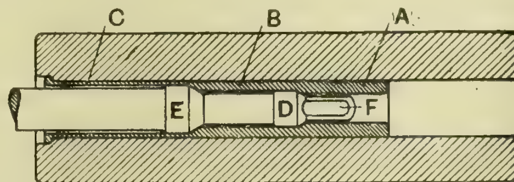
The Journal of the Textile Institute. Edited by T. W. Fox and J. Hübner. Vol. III., No. 1. Manchester: 14, Cross Street.

Iron and Steel Institute. Carnegie Scholarship Memoirs. Vol. IV., 1912.

Board of Education Reports for the Year 1911, on the Geological Survey, the Geological Museum, and the Science Museum. Published by H.M. Stationery Office. Price 9d.

EHRHARDT PROCESS FOR PRODUCING TUBES FROM BLANKS BY DRIFTING.

A PATENT recently granted to H. Ehrhardt, 20, Reichsstrasse, Düsseldorf, Germany, relates to a method of producing tubes or pipes by drifting with the aid of a mandrel which is forced through a short tubular blank or work suspended by means of a marginal collar or thickened portion at one of its ends. It has already been proposed to produce tubes from a short tubular blank or billet supported in this manner and without additional support during the drifting action, but in this case during the expanding action a back support is required, or else two mandrels are required acting on the billet in opposite directions, so that after the initial operation of expanding and securing the ring billet in the die has been completed one of the mandrels is moved out of action by the other, which latter alone continues to draw out the ring billet into tubular form. In contra-distinction to these known methods the one under notice consists in using a tubular blank suspended in a matrix by means of a marginal collar or thickened portion at one of its ends, and employing a single mandrel so dimensioned as to first act initially with an expanding effect whereby the outer material of the blank is forced against the matrix walls and



EHRHARDT PROCESS FOR PRODUCING TUBES.

the blank is thereby held in position without any additional support while the drifting operation is proceeding with the aid of the same mandrel.

Referring to the illustration, A indicates the tubular blank or its original thickness. B is the part of the blank after its preliminary expansion, and C is the finished or actual pipe portion thereof. The mandrel is provided with a preliminary or expanding head D, and with a final or drifting head E. These two heads are connected by a short stem, and the expanding head D is provided with a guide portion F. This mandrel has the object to first expand and firmly press the material of the blank against the matrix walls by means of the expanding head E, thereby producing a strong frictional grip which prevents the pipe portions C from being torn away from the wall of the matrix by the action of the drifting head E. As therefore the outer material of the blank firmly adheres to the matrix wall the tube is completed solely by the displacement of the inner material of the blank by the drifting head. The guide portion F is provided with recessed faces, so that only the remaining concentrical portion is caused to bear against the blank so as not to cool it too much.

THE INNER STRUCTURE OF SIMPLE METALS.*

BY SIR J. ALFRED EWING, K.C.B., LL.D., F.R.S.

(*Concluded from page 174.*)

CONFINING our attention for the present to the cubic system, there are, as we have seen, three possible modes of piling; first, the most open piling with each spherical unit touching six others; second, the medium-close piling with each unit touching eight others; and lastly the closest mode, with each unit touching twelve.

Now we come to a highly interesting question. Assuming that the structural units of the crystal behave like spheres



FIG. 24.

piled in one of these various modes, what mutual forces do they exert on one another to make them fall into place and remain in place? Can we think of them as having polarity, in virtue of which each assumes its proper orientation and position? And if there are such polar forces among the structural units of the crystal, do they assist us to explain any of the known physical properties of the substance?

In an address to the Engineering Section of the British Association at York, in 1906, I attempted to suggest answers to these questions, on the supposition that the units were grouped in the first or most open mode of piling. I showed that we should get that mode of piling if we supposed each unit to have three rectangular axes with opposite poles at their extremities, making six poles in all, three positive and three negative.† Some of the consequences were illustrated by means of a model, in which the interactions of such units were shown, the units in the model being composed of crossed magnetised bars, free to turn on fixed needle points as pivots. If there is any such polarity in the units of a crystal, it is no doubt electric, not magnetic—we may think of the unit as containing within itself a group of electrons—but it is con-

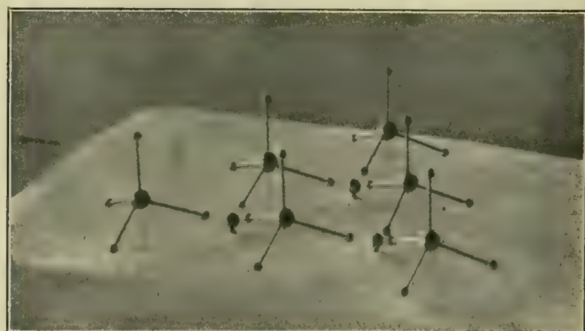


FIG. 25.

venient to make use of magnets in the construction of a model. They give us mutual forces of the same general character as we get with electrons, namely, attraction between unlike poles and repulsion between like poles.

A model arranged in that way shows how, as one after another molecule or unit is brought up, it takes its place as a member of the homogeneous assemblage, assuming the proper orientation as it settles down. You may disturb the assemblage by forcing any one member to turn round a bit, and then letting it go, when you see waves of disturbance passing from unit to unit. A violent disturbance may set many of the units spinning, and when they settle down again you sometimes find that they are not all homogeneously grouped, but some have taken up a position of less stability. They have formed what may be called a dissenting group, the members of which keep one another in countenance, though they are not in complete harmony with their environment. If we set them oscillating, so as to imitate the effect of raising the temperature, we may find this less stable group break up and fall into line with their neighbours. Something of this kind occurs in the annealing of a metal. One might say that nature copies the methods of the mediæval Church in bringing dissenters to reason by the application of heat.

There are other points on which such a model throws light. We can use it, for instance, to show what happens when slipping occurs, and this we may illustrate by the single-layer model now in the lantern. Suppose that one portion of the crystal slides past another portion, we imitate that action by causing one group of the pivoted particles to slide past another group. Notice the effect. Across the plane of sliding the polar forces continue to act, causing first a quasi-elastic turning; but when a certain very limited range of movement is exceeded there is dissipation of energy through the original bonds being broken and new bonds established, with oscillation of the particles. The model exhibits well the essential difference between elastic and plastic strain, and shows how it is that work has to be expended irrecoverably in making a plastic strain occur.

In this model we have obtained the mechanical forces which the particles have to exert upon one another by the device of supposing positive and negative polarity within each unit. It would do equally well to take an equal number of positive and negative units—that is, a number of units in which all the six

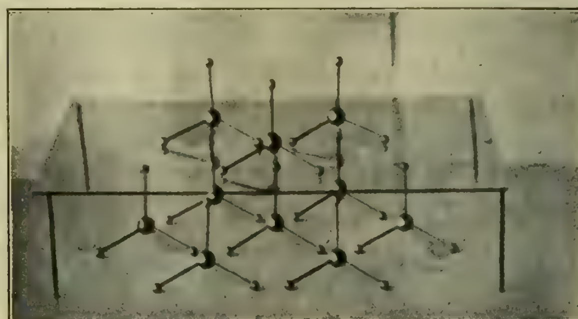


FIG. 26.

poles are positive and an equal number in which all the six poles are negative. If we jumble these up together, but give them freedom to assume their most stable grouping, they will necessarily take up the same configuration as in this model, namely, the most open mode of piling with cubic symmetry.

Again, if instead of six-pole units we were to take eight-pole units, keeping equal numbers of positive and negative units, but letting each unit have eight poles of the same name, we should find them assume the second mode of piling, the mode illustrated by red and white balls in Fig. 19.

But I am more interested in the question: What sort of polarity must we postulate in order to get the closest mode of packing? There seem many grounds for believing that it is the closest mode of packing rather than the open modes which the crystal units actually assume. It is true that Prof. Sollas* favours the idea of open packing for metals crystallising in the cubic system; and Kelvin accepted as probable alternatives all three modes, the close, the medium, and the open;† but Mr. Barlow and Prof. Pope, in much of their recent work, have given what seem strong grounds for thinking that in general crystalline constitution is that of closest packing.‡ However that may be, let us face the problem of what arrangement of poles could produce closest packing. The first models I tried were tetrahedra with four poles.

* Lecture delivered before the Institute of Metals, May, 1912.

† British Association report, 1906. Presidential address to the Engineering Section.

* W. J. Sollas "On the Intimate Structure of Crystals." Proceedings of the Royal Society, Vol. LIII., 1898.

† See especially his "Molecular Dynamics of a Crystal." Baltimore Lectures, page 672.

‡ W. Barlow and W. J. Pope, "The Relation between the Crystalline Form and the Chemical Constitution of Simple Inorganic Substances." "Journal of the Chemical Society," Vol. XCI., 1907.

These, and also the other models which have still to be brought under your notice, are magnetic models. They are built up by taking a central boss, which may conveniently be a steel ball, screwing rods of equal length into it, with a small steel ball upon the outer end of each rod. Then the rods are magnetised, so that all the outer balls become poles of the same name, while the central boss forms a pole of the opposite name. In the first model (Fig. 24) there are four rods and four circumferential poles, forming the corners of a regular tetrahedron; all these are south poles, while the central ball is the north pole. There is

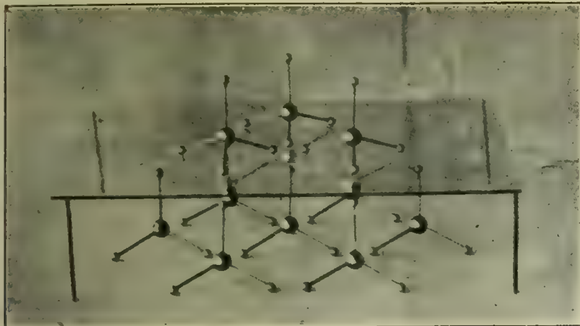


FIG. 27.

also a pivot hole drilled in the central boss, and the base board carries needle centres, which are equilaterally spaced in triangular order, and on these the little four-pole magnets are balanced, so that they turn freely under the mutual repulsion of the external poles.

They assume the configuration shown in Fig. 24, which is in fact a photograph of a single layer of such pivoted units after it has come to rest. It is a very regular configuration, but it is not consistent with cubic symmetry, because the faces of the pivoted tetrahedra do not place themselves so as to be similarly related to the four octahedral planes of the system, of which the table top is one.

Suppose, however, that we introduce a new element, modifying the equilibrium. Let each structural unit be associated with what I shall call provisionally a "cementing corpuscle," namely, an isolated pole, opposite in sign to the circumferential poles of the units. If they are electrons, it is an electron of the opposite kind. Think of this "corpuscle" as finding its habitat in one of the interstices between the closely-packed spheres. As soon as we accept this idea we find there is no difficulty in getting the units to pile up into most satisfactory crystals, by placing themselves unit by unit and layer upon layer, so that they satisfy the condition of cubic symmetry.

Fig. 25 shows a small group of pivoted four-pole units, forming a single layer, in the positions which they assume

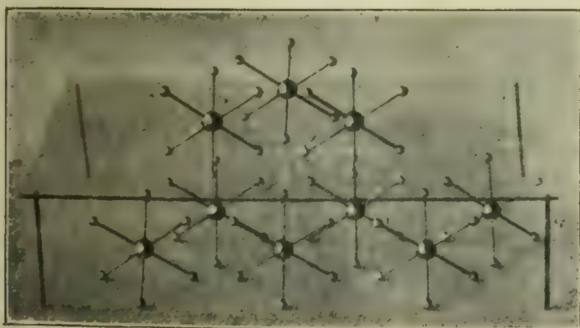


FIG. 28.

under the influence of the "cementing corpuscles." These bodies are visible in the figure as isolated poles in the interspaces, and towards them the arms of the tetrahedra point. In the magnetic model shown in this photograph these isolated poles are obtained by using long wire magnets, of which they are the upper ends, the remainder being below the table.

In the model the pivots are at the corners of equilateral triangles, so as to simulate the conditions of closest packing. A more complete model, with two layers, is shown in Fig. 26, the upper layer being supported on a glass plate. The pivots are omitted, but the pieces are placed in the positions of equilibrium which they would take up under the influence of the corpuscles. The corpuscles themselves are not represented in the model, but you are to imagine that they are. Each corpuscle (in an extended assemblage of the type shown in Fig. 26) occupies the centre of a tetrahedral cluster of four poles contributed by four neighbouring units, the corpuscle being, of course, opposite in sign from the poles, and causing the poles to point towards it.

The whole group in Fig. 26 may be regarded as representing the middle and top layer of one of the "mulberries" of Fig. 23. You can imagine a bottom layer to exist, and if its units are not in the position vis-à-vis to the units of the top layer, but in the alternative position, we have an assemblage possessing cubic symmetry.

Now return for a moment to the model with balls. I want you to think of what happens when twinning occurs. Twinning will occur on this plane if the top layer be turned round through 180°; and that means that the balls occupy the alternative hollows in the layer of balls below them.

Here (Fig. 27) we have them so grouped in the magnetic, or rather the polar, model. The two layers are now in twin relation with one another. The three units on the top are each turned round through 60° (which is equivalent to a turning of them through 180°), and are shifted into the other set of hollows; and those two movements, the turning and shifting, cause the poles to engage again with the corpuscles. The interesting point about this particular case is that they are just as stable in the new position as they were before. Therefore this model, to my mind, has the serious objection that it makes twinning far too easy. It appears to be an even chance in this case when any layer is deposited

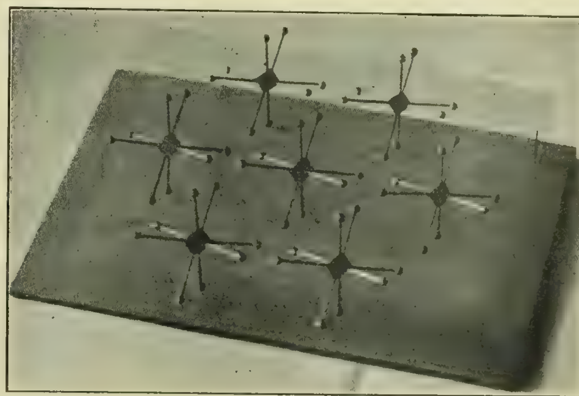


FIG. 29.

whether it is deposited in the regular cubic form or in the twin form.

A few words of explanation may be required here to prevent a possible misunderstanding. In speaking of Fig. 23 I said that if we turned the top layer round through 180°, as in the right-hand figure, we passed from cubic to hexagonal piling. Now, you observe, I also say that the turning of the top layer round means the beginning of the formation of a twin. To reconcile these two statements, you must think of what happens when we go on to place other layers above the three. If in placing a fourth, fifth, sixth layer, and so on, we follow the same rule as in the right-hand mulberry of Fig. 23, putting the balls in each layer vis-à-vis with those in the layer next but one below, we get a hexagonal crystal. If, on the other hand, the change from regular cubic piling occurs at one plane only, and after the changed layer has been laid down the succeeding layers are piled cubically with respect to it, we have a twin structure in which the plane at which the change occurs is a junction plane connecting two portions which are in twin relation to one another, each of which possesses the symmetry of the cubic system. It may help to make the point clearer if I add that we may regard hexagonal piling as equivalent to cubic piling with twinning on every layer.

Pass now to this other model (Fig. 28), where each structural unit has six poles, situated at the ends of three rectangular axes, or, in other words, at the six corners of a regular octahedron. Imagine as before that the poles are all

of the same sign in all the units, and that there are corpuscles of opposite sign in the interstices between the units — one corpuscle per unit. The units group themselves in closest-packed cubic order as in the figure, each corpuscle engaging six poles, which form an octahedral cluster around it. There is only one corpuscle required per structural unit. If we attempt to change the upper layer into the position for twinning, by turning the units in that layer through 180°, and shifting them over to the unoccupied hollows of the layer below, we shall find that we leave three balls unengaged. The "cementing corpuscle" then engages with only three

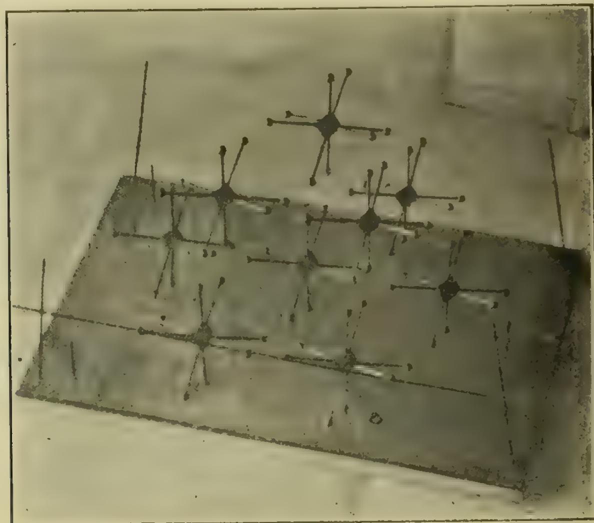


FIG. 30.

poles at the twin surface, leaving three poles with their affinity for a corpuscle unsatisfied, and therefore I should say that with this six-pole model twinning is unlikely to occur.

Finally, consider a model in which each unit has eight poles situated at the corners of a cube (Fig. 29). In this case the central boss is shaped as a cube, instead of a ball, simply for convenience of construction. Fig. 29 shows a single layer of such units; Fig. 30 shows two layers, the upper layer consisting of three units. They are in closest-packed cubic grouping. To hold them in this position requires two corpuscles per unit instead of one, and, as before, you are to imagine the

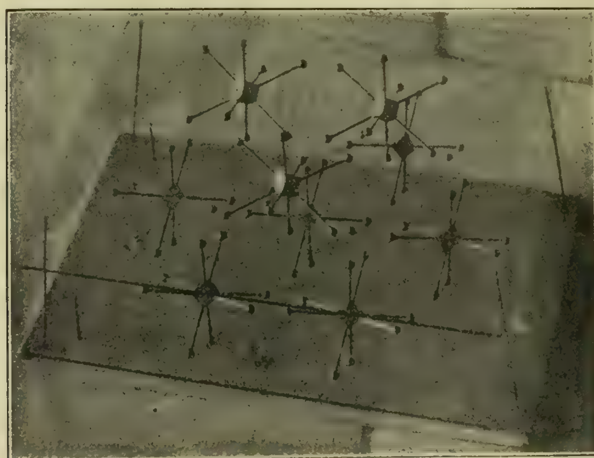


FIG. 31.

corpuscles to be present though they are omitted in the model. Each corpuscle engages with four poles, which form a tetrahedral cluster around it. If we attempt to pass to the twin formation by turning and shifting the units of one layer as before, we get that formation with three balls satisfying their affinity for the corpuscle and only one disengaged. Consequently we have here what seems to me an exceedingly possible form so far as twinning is concerned, inasmuch as the twin formation, although less likely to occur, is not very much less likely. The stability is not so very different in the two cases.

Fig. 31 shows the same group as Fig. 30, but with the three units which constitute the upper layer turned and shifted into the twin position. It is to be feared that these models are scarcely comprehensible when displayed in photographic pictures. They should be seen at close quarters, with two eyes, and the units should be handled, to have their grouping properly appreciated.

Some one may be inclined to ask, how can you imagine hexagonal formation to occur? We may, as I have said, regard hexagonal formation as cubic formation with twinning on every layer (perpendicular to the axis of hexagonal symmetry). But that does not help us if we wish to conceive of a polarity in the structural units which will compel them to adopt hexagonal piling. One may obtain that by taking a model in which each unit has five poles, two at opposite ends of an axis and the other three ranged round the equatorial plane at angles of 120° apart. With such units as these, and with one "cementing corpuscle" per unit, you can build up of necessity nothing else than the hexagonal closest-piled structure.

These points require more illustration than can be given in the limited time of a lecture and without handling the actual models. I have not been able to do more than indicate the scope of the speculations. They make no claim to form a theory or even part of a theory of the constitution of matter. They are rather an attempt to hint at directions one may pursue in search of a solution to the problem; one might compare them to sign-posts on open moorland seen in a fog. They do not satisfy our intellectual curiosity; I shall think they have served their purpose if they stimulate it. In studying molecular structure, we find ourselves in the case described by the Persian philosopher-poet who frequented the doctors—

"And heard great argument
About it and about, and evermore
Came out at the same door as in I went,"

It is a study that disappoints and baffles, but even if one feels there is no achievement, its fascination remains. We may never succeed in removing or penetrating the veil, but we are not likely to abandon the effort. As the caged beast goes on beating against his bars, so man will continue to strain after knowledge which, for all that he can tell, may be for ever out of reach.

EXPLOSION OF AIR RECEIVER DUE TO OIL.

BY FRANK RICHARDS.

A SMALL air receiver connected with a portable gasoline engine driven air compressor, employed on street gas-pipe work, exploded on June 24th, near the entrance to Greenwood Cemetery, Brooklyn. The occurrence exhibited a number of interesting features illustrative of the conditions under which such accidents may occur. There seems to have been no sudden and enormous increase of pressure, such as would be caused by the ignition of an explosive mixture composed of volatilised constituents of the oil combined in suitable proportion with the compressed air; the normal working pressure which the receiver usually carried was probably not much if at all exceeded; nevertheless it seems to have been ultimately a simple pressure explosion, but accompanied by abnormal conditions which provided the opportunity.

The receiver was suspended horizontally under the frame which carries the gasoline engine and the compressor. It was 6ft. long and 2ft. diam., with dished heads; the convex side of the head was outward at one end and the concave side outward at the other end, which is the too common practice, just for convenience in riveting in the last head, and for no other good reason. The air entered the receiver from the compressor about 2ft. from one end and half way up, and was taken out at the other side just opposite the inlet (see Fig. 1). A pop safety valve on the pipe from the compressor was set at 110lbs., and the usual working pressure was about 100lbs.

As disclosed after the explosion, the entire interior surface of the receiver was covered apparently with all the oil it could carry. If the operator had been told to use all the oil he could, instead of as little as possible, the surface could not have been more oily. From time to time all the oil and water which might have collected at the bottom of the

receiver should have been drained off; this may or may not have been done, but evidently it would not have made the surfaces clean, nor have freed them from the gummed or thickened oil with which they were coated.

The inner surface, A, Fig. 1, of the head which blew out, however, was dry and absolutely clean, and its colour and condition showed that it had been red hot. Evidently a local fire had raged, perhaps only for a minute or so, on this (then oil-coated) surface, burning the oil off and suddenly heating the plate; the fire did not have time to spread to the adjacent surface of the shell when the explosion occurred.

In the explosion several curious things happened which it is worth while to note carefully. The head became so hot



Fig. 1.—Horizontal Section through Receiver.

that, as it was under about all the air pressure it could stand, the dishing of the head was suddenly reversed, and the originally convex surface became concave, as shown in Fig. 2, this being a view of the inner surface. That this is the inner surface of the head is corroborated by the lip at the edge of the sheet. The ridge which is dented across the face was evidently caused by something against which the head struck as it flew off.

It is easy to imagine that this reversal of the dishing of the head took place with a considerable snap, the shock and momentum, in addition to the aggregated air pressure of 45,000lbs., being sufficient to cause the head to let go. When it did, not a single rivet was sheared. It will be noticed from Fig. 2 that when the reversal of the dishing occurred, the rivet-carrying lip of the head was bent outward all the way around, so that the opposite sides, instead of being parallel, stood off 30° to 45° from the normal position, and the end of the sheet to which they were attached (see Fig. 3) bent outward in the same way. There were 80 $\frac{5}{8}$in. rivets, and when the lip was bent out their heads were pulled off, dropping outside the shell, and then the rivets pulled out of the holes. The fracture of the rivets was square across under the heads and flush with the outside of the shell. Of the 80 rivets, three retained their heads, and those tore notches out of the shell.

When the head flew off, the body of the receiver was driven in the opposite direction, but could go only a few inches when it struck the axle of the machine, which dented the head. Other than this the shell seems to have received no damage.

Undoubtedly receivers have often taken fire internally, as indicated in this case, but having a sufficient factor of safety, in spite of the heating of the metal, they have been able to withstand the stress and no accident has resulted.

The interesting question is as to the conditions causing, or accompanying, these ignitions of the oily surfaces, and usually more or less mystery is made of this phenomenon when it occurs. Compare the oil tempering of steel springs. The spring is first heated in the fire to a bright red and then plunged into oil and cooled. This leaves it hard and brittle, and it is then drawn to the proper temper by "blazing off." To do this, the spring, while dripping with oil, is held over the fire, which must be without flame, and is slowly and carefully heated until the oil on the spring bursts into flame. The oil is not ignited by the fire, the flame merely appearing when the spring reaches the right temperature. The oil will keep burning until consumed, or the spring, while blazing, may be dipped into the oil and the flame will go out, but if quickly withdrawn the flame will appear again. At a certain temperature oil will ignite spontaneously, and this temperature is so fixed, differing, however, for different oils, that it has been taken for generations as an index of the heat required for the tempering of springs, swords, &c.

Precisely the same thing that happens in the oil-tempering of springs will happen to the oil-coated surfaces of air reservoirs, pipes, &c., when they get hot enough. The oil will take fire of itself without any spark, flame, or other extraneous source of ignition. The oil-covered steel spring, when the oil upon it takes fire in the open air, is below a visible red heat, and that begins at about 700° Fah. In the air receiver under consideration, the temperature due to compression may have been as high as 500°. With air at 60° when compression begins, the theoretical terminal temperature, after adiabatic compression to 105lbs., is 496°. This compressor was running in bright sunshine on a hot day, and the intake air passed close to the already heated air receiver before entering the cylinder, so that its temperature at the beginning of compression was presumably above 100°, and its terminal temperature above 500°. There being nothing at the end of the receiver to cause any active movement of the air in contact with the oily surface, may have offered special opportunity for the atoms of carbon and oxygen to unite. Furthermore, since the air was compressed to eight atmospheres the oil was exposed to eight times the amount of oxygen that it would have at atmospheric pressure. This may partly account for the spontaneous ignition of the oil at a lower temperature and its burning more fiercely after ignition.

An account of an ignition of this character recently appeared in "Mines and Minerals," and was reprinted in "Compressed Air Magazine," June, 1912. No damaging explosion occurred, however. It was in connection with a 4-stage compressor employed for charging locomotives. The ignition took place after the fourth stage of the compression, when the air was at a pressure of 65 atmospheres, and a recording thermometer, which was attached and in operation, showed that the ignition took place at 270°, which seems to corroborate the assumption that the higher the pressure the lower will be the temperature at which spontaneous ignition will occur.

This discussion distinctly avoids any consideration of the more disastrous class of compressed-air explosions caused by the ignition of an explosive mixture of air with some of the volatilised constituents of the oil, as there seems to have been nothing of that in this case.—"Power."

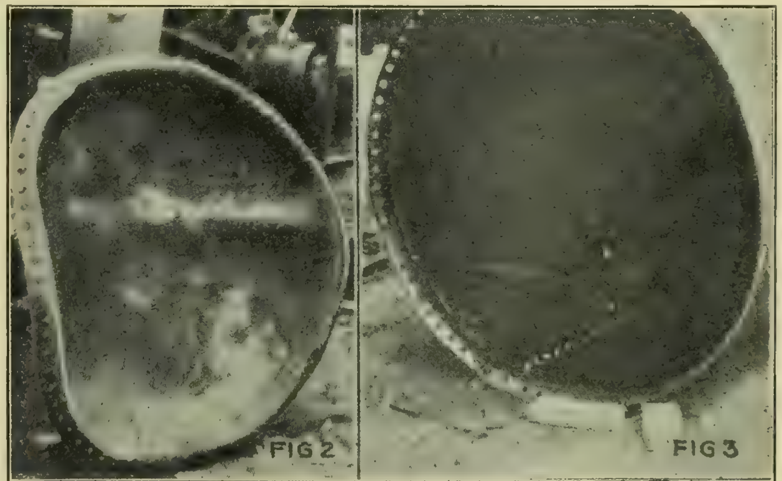


Fig. 2.—Inside Face of Head after Explosion. Fig. 3.—Showing Flaring End of Shell with Rivets pulled out.

Oil Fuel for Marine Purposes.—There seems to exist a general opinion that the relative advantage of this country will be changed materially for the worse by the adoption of oil for marine propulsion owing to the fact that great oilfields do not exist so far as is now known in this country. This is not the view held in the best informed naval circles. It is, of course, recognised that there will have to be a vast storage of oil in this country, and conceivably great engineering works may be required to secure such a supply. But the strategical advantage lies in the fact that oil is now, and in the future will be so still more, always in transit in tank vessels which can be directed upon particular courses, and the position of each vessel reported by wireless telegraphy. In this way it will be possible for British vessels in all parts of the world to replenish their oil tanks at sea, whereas no such facilities exist in the case of coal.

ADJUSTING DEVICE FOR ROTARY GRINDING MACHINES.

We illustrate herewith a device for enabling the setting of the wheels or discs of grinding machines to be rapidly effected, the invention of Messrs. Ludw. Loewe & Co., Huttenstrasse 17-19, Berlin, N.W. The device enables the grinding wheel or disc to be set or adjusted at different speeds as required by a crank through the medium of an epicyclic gear, the sun wheel of which is adapted to be operated at different speeds by locking or releasing the epicyclic gear as desired.

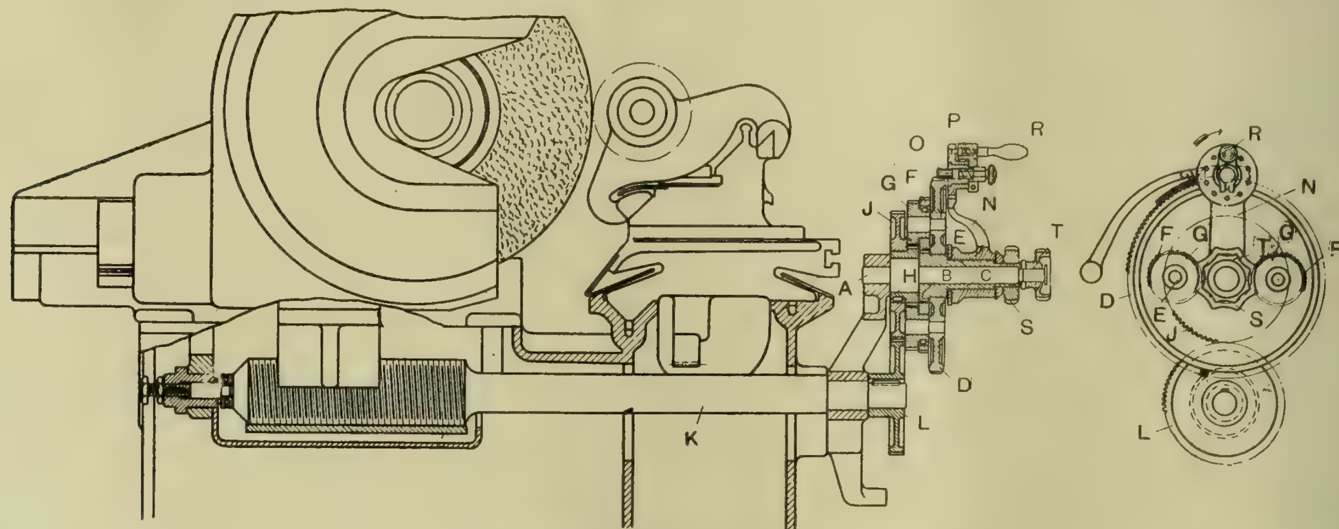
Fig. 1 shows the apparatus in side sectional elevation, while Fig. 2 illustrates a detail in front elevation. A journal A is mounted in the frame of the machine in such a manner as to be held from rotation, and a gear wheel B, whose hub terminates in a sleeve C, is loosely mounted thereon. A second gear wheel D is rotatably mounted upon the sleeve C, and is provided with pins E, which extend in a direction parallel to the axis of the gear wheel B and are provided with gear wheels F and G. The gear wheel F, which is keyed to the hub of the wheel G, is in mesh with the gear wheel B, while the wheel G engages with a gear wheel H loosely mounted upon the pin or journal A. To the gear wheel H is keyed a gear wheel J engaging with the gear wheel L secured to the driving spindle K, through the medium of which the setting or adjustment of the grinding wheel or disc is effected. The hand-operated crank N is also mounted upon the sleeve C, and is provided at its end with a gear wheel O which engages with the wheel D and is adapted to be rotated through the medium of the crank P. The wheel O can be locked in any position by a spring-controlled locking pin R, and the crank N which is loosely mounted upon the sleeve C is adapted to be clamped or fixed in position on the sleeve C by means of a nut S, so that the sleeve is driven by the crank when the latter is turned. The sleeve C in its turn may be clamped in position upon the journal A by tightening a nut T, and when required, both the crank P and the crank N may be rotated by means of the index pin R, which conveniently takes the form of a handle.

The operation of the apparatus is as follows: If it is required to adjust or set the grinding wheel or disc slowly for the purpose of obtaining a fine or very minute adjustment the nuts S and T are tightened up so that the gear wheel B and the crank N are connected to the stationary pin or journal in such a manner that they cannot rotate. The spindle K is then driven by turning the crank P, which, in its turn, rotates the gear wheel O, and through the medium of this latter and the gear wheels D F G H J and L the spindle K, and consequently the grinding wheel support, together with the grinding wheel or disc, is moved up to or away from the work to be ground, depending upon the direction in which the crank P is rotated. As in this case the gear wheel B is clamped in position upon the spindle A the gear wheel F rolls upon the wheel B, and consequently drives the gear wheel G.

If the setting operation of the grinding wheel or disc is to be accelerated the nut S is slacked back while the nut T remains tightened up, and the crank N is thus free to rotate upon the sleeve C, while the latter, together with wheel B, is fixed upon the pin A so that it cannot rotate thereon. The wheel O is locked to the crank P by means of the pin R, so that it forms, as it were, a driver or driving connection between the crank N and the gear wheel D.

When the crank N is rotated by means of its handle R the gear wheel D is driven by the wheel O at the same speed, but the wheel F still rolls upon the fixed wheel B. The action of the gear is therefore similar to that described above, but the speed is somewhat accelerated, due to the fact that the gear wheel D is driven at the same speed as the crank N, and not at the much slower speed by means of the gear wheel O, as above described.

If the grinding wheel or disc is to be moved through a greater distance still, then it is advisable to still further accelerate the movement of the grinding wheel support, and for this purpose the nut T is also loosened and the crank N is firmly connected to the wheel B through the medium of the nut S, so that the crank N drives the wheel B, and the wheel O, acting as driver or driving connection, drives the wheel D. As the wheels D and B are coupled together the wheel F can no longer roll upon the wheel B, but, on the contrary, it is locked, so that the wheel G rigidly connected to the wheel F acts as a driver which, in its turn, directly rotates the wheels H and J. The entire gear wheel connection thus forms a united whole, so that the wheel J has the same rotary speed as the crank N, and the setting of the grinding wheel or disc is thus effected more speedily.



Adjusting Device for Rotary Grinding Machines.

Assuming a crank shaft is to be ground down on both sides of the crank to the same diameter, then, after one side of the shaft has been ground down to the correct diameter, the grinding wheel or disc support must be moved backwards until the grinding wheel or piece of work is clear. Thereupon the work is moved to such an extent that the other part of the shaft comes opposite to the grinding wheel or disc. The setting movement of the grinding disc or wheel support can first of all be effected by fine or coarse setting by turning the crank P, arranged on the crank N, through one revolution in the direction indicated by the arrow, whereupon it is left to the discretion of the operator, by turning the crank N and locking the crank P through the medium of the index pin taking the form of a handle R to effect the moving back of the grinding wheel or disc support by means of the coarse adjusting or intermediate adjusting gear depending upon whether the nut T is tightened or loosened. In order to return the grinding disc to the piece of work, the crank N is thereupon turned back through the same number of revolutions until the same comes again into contact with the abutment. If the crank P, after the index pin R has been loosened, is again moved through a whole revolution in the direction opposite to that indicated by the arrow, then the grinding disc support is by this means moved forward through exactly the same distance through which it was previously moved backwards.

POWER CONSUMED IN DRIVING LOOMS.*

BY J. GORTON.

WITH the object of providing some definite particulars regarding the power consumed in the driving of a fully-equipped loom, it has been thought advisable to carry out a series of experiments in this direction on a number of looms in the weaving shed of the Manchester School of Technology. A number of looms were selected and suitable means provided for driving these looms whereby the power consumed could be accurately determined. Electrical means were resorted to, a ¼ h.p. electrical motor being used. The necessary particulars for obtaining the power consumed were registered on a combined ammeter and voltmeter, a recording ammeter being used to show the varying current during the time the looms were running. The speeds of both motor and looms were taken by the aid of a tachometer. For one complete set of experiments the same warp, loom pulley, and drum were used in all the looms; this was done to clearly show up the relative differences due to loom construction and equipment, whilst to show the differences due to weave and class of cloth, another warp was placed in the same loom and tests made. In the looms where warp stop motions were employed, tests were made to show the effect of working with the stop motion and without the stop motion, and again, looms fitted with checking mechanism were tested whilst the motion was in gear and whilst the motion was out of gear. To give a clear idea of the variations which were observed, it will be necessary to explain the equipment of each loom fully. It might be said that altogether six different looms were experimented upon. These we will call A, B, C, D, E, F. In making the following tests care was taken to secure uniform current. Each loom was thoroughly oiled and worked for not less than two hours before taking the readings. This was done so that all parts would be in good working condition at the time of testing. The following are the particulars of the warp used in making the plain cloth tests in all the looms, and will be referred to as the plain warp:—

2,240 ends .... 34's twist.
50 picks .... 20's weft.
78 reed .... 28½in. width in reed.

Loom A.—41in. reed space. This is a loom known as "Pickler's Ideal Loom," made by Butterworth & Dickinson, Burnley, fitted up for ordinary plain work.

Power test: 162 picks per minute; amps., 1·7; volts, 223; net h.p., 0·3423.

Loom B.—40in. reed space. Sateen loom, made by Butterworth & Dickinson. To make this test comparable with the other the usual changes were made to weave plain cloth, using the plain warp. One test was made with an electrical wire warp stop motion, another test made with the stop motion taken out.

Power test, with warp stop motion: 160 picks per minute; amps., 1·75; volts, 227; net h.p., 0·3667. Without warp stop motion: 161 picks per minute; amps., 1·65; volts, 227; net h.p., 0·3362.

Loom C.—40in. reed space. Another loom made by Butterworth & Dickinson, fitted with Cowburn & Peck's drop-box checking motion, the tappets being fixed on a countershaft driven from the bottom shaft. The first test was made without using the checking motion, but in the second test the box motion was employed weaving a pattern requiring three shuttles.

First test, without checking: Picks per minute, 150; amps., 2·5; volts, 220; net h.p., 0·5714.

Second test, with checking: Picks per minute, 150; amps., 2·5; volts, 222; net h.p., 0·5781.

Loom D.—40in. reed space. Makers, Butterworth and Dickinson, Burnley. A sateen loom, five shafts of the top roller type, the tappets being fitted on a countershaft. The loom is also fitted up with an electrical warp stop motion (drop wires). Changes were made to weave plain cloth and the first test made without using the stop motion, then a similar test made with the addition of the stop motion.

First test, without stop motion: Picks per minute, 159; amps., 1·9; volts, 225; net h.p., 0·4072.

Second test, with stop motion: Picks per minute, 156; amps., 1·95; volts, 219; net h.p., 0·4066.

* From the Journal of the Municipal School of Technology. Vol. V.

Loom E.—41in. reed space. Maker, Henry Livesey, Blackburn. Tappet loom with overhead shedding, stocks and bowls underneath, weaving five-end satin. To weave plain cloth in this loom the tappet was placed on the bottom shaft and a top roller put on.

Picks per minute, 158; amps., 1·75; volts, 220; net h.p., 0·3502.

Loom F.—British Northrop Loom Company, Blackburn. At the time of making the test the cloth being woven was a five-end twill, but of course, as in the other looms, this was changed to weave plain cloth. The tappets are fixed on a countershaft driven from the bottom shaft, no warp stop motion being used.

Picks per minute, 155; amps., 1·65; volts, 217; net h.p., 0·3141.

The following table shows the results of the tests on plain cloth:—

Loom.	Reed Space.	Picks.	Amps.	Volts.	Net H.P.	Particulars.
A	41in.	162	1·7	223	0·3123	
B	40in.	160	1·75	227	0·3667	With stop motion
B	40in.	161	1·65	227	0·3362	Without stop motion
C	40in.	150	2·5	220	0·5714	Without checking
C	40in.	150	2·5	222	0·5781	With ,,
D	40in.	159	1·9	225	0·4072	Without stop motion
D	40in.	156	1·95	219	0·4066	With ,, ,,
E	41in.	158	1·75	220	0·3502	
F	41in.	155	1·65	217	0·3141	Without ,, ,,

After the tests for plain cloth were taken, the looms were changed on to their own warps and further tests made with the following results:—

Loom B.—40in. reed space; 35½in. width in reed; 2,960 ends, 2/50's twist; 80 picks per inch, 30's weft. Weaving five-shaft sateen with side tappets, cross-rods, and Kenyon's spring-easing under motion.

Without warp stop motion: Picks per minute, 164; amps., 1·65; volts, 226; net h.p., 0·3340.

With stop motion: Picks per minute, 160; amps., 1·65; volts, 220; net h.p., 0·3207.

Loom D.—40in. reed space; 36in. width in reed; 2,900 ends, 2/50's twist; 82 picks, 30's weft. Weaving five-end sateen, roller top.

Without warp stop motion: Picks per minute, 160; amps., 1·9; volts, 219; net h.p., 0·3919.

With warp stop motion: Picks per minute, 157; amps., 1·95; volts, 218; net h.p., 0·3951.

Loom E.—41in. reed space; 27in. width in reed; 3,060 ends, 34's twist; 60 picks, 16's weft. Weaving five-end satin, overhead shedding, stocks and bowls underneath.

Picks per minute, 160; amps., 1·65; volts, 220; net h.p., 0·3207.

Loom F.—41in. reed space; 37in. width in reed; 2,600 ends, 2/40's twist; 70 picks, 24's weft. Weaving five-end twill with warp stop motion, and positive warp let-off motion.

Picks per minute, 152; amps., 1·85; volts, 222; net h.p., 0·3874.

I should like to thank Prof. Fox and Mr. Myers for their kind advice in the compilation of this paper, and also Mr. W. H. Rycroft, a former student of this school, for his assistance in making the tests.

Summary of Results.

Loom.	Reed Space.	Picks.	Amps.	Volts.	Net H.P.	Particulars.
B	40in.	164	1·65	226	0·3340	Without stop motion
B	40in.	160	1·65	220	0·3207	With ,, ,,
D	40in.	160	1·9	219	0·3919	Without ,, ,,
D	40in.	157	1·95	218	0·3951	With ,, ,,
E	41in.	160	1·65	220	0·3207	Without ,, ,,
F	41in.	152	1·85	222	0·3874	With ,, ,,

Fatal Derrick Accident.—A fatal accident occurred at the Cleveland dockyard of Sir Raylton Dixon & Co., Ltd., Middlesbrough, on the 8th inst. A number of men were engaged in removing the upright staging poles from a vacant shipbuilding berth, and in order to pull the poles out of the ground a derrick, 70ft. high, was used. During the operations the guide rope of the derrick broke, and the structure fell. One of the men was caught by the derrick and instantly killed. Five other workmen were struck by falling material and injured.

MODERN BRASS FOUNDING.*

BY H. S. PRIMROSE, M.I.M.

In modern brass founding the chief considerations to be kept in view are economic working and scientific control. The former is largely brought about by the adoption of various labour-saving devices, which reduce most of the operations to mechanical repetition, and a systematic lay-out of the plant which allows of the metal passing through the various stages of treatment in a straightforward direction. The control of the metal must be complete, beginning with the raw material and tracing it through all departments until it is sent out as a finished product. This scientific control should deal not only with the chemical composition but also with the physical tests, and, wherever possible, with the microstructure in addition. It must be stated at the outset, in order that the term "brass founding" may not be misunderstood, that the principles and practice detailed in this paper deal first of all with what is really a bronze, technically known as Admiralty gun-metal, and containing 88 per cent. copper, 10 per cent. tin, and 2 per cent. zinc, according to specification. The details of working are, of course, equally applicable, with the necessary modifications, to the founding of true brass containing only copper and zinc.

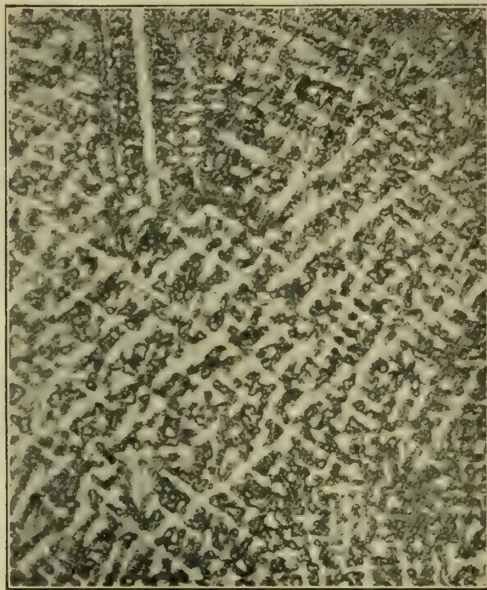


Fig. 1.—Microstructure of Good Gun-metal. Magnified 30 Diameters.

The important point to be considered in designing a brass foundry is the provision of ample light and ventilation, and this is best accomplished by having high roofs copiously glazed, and provided with numerous openings through which the fumes and gases can escape readily. Poor ventilation in brass foundries is highly injurious to the health of the workmen, and the employer who is interested in the welfare of his employés will give the subject of ventilation careful consideration, and also install good sanitary arrangements. In many of the most up-to-date foundries all the employés are provided with lockers, and a sufficient number of wash-basins are provided for their use. The expense of these arrangements quickly repays itself by the increased efficiency of the operations performed under healthful conditions.

The type of furnaces to be used will depend upon the class of metal employed and the size of the castings to be made. For small gun-metal work the ordinary coke-burning crucible furnace is suitable where the output is not large, but for larger work it is advisable to have a reverberatory furnace of convenient size. The pot fires are best arranged in a battery placed at floor level, in front of which are the ash pits covered by a grating on which the melters can stand, and behind the fires the individual flues run into the main flue connected with the stack. The furnaces should be placed contiguous to the metal store, moulding floor, and dressing shop. At the back of the metal store may be placed the platform at the side of the air furnaces, in front of which is arranged the moulding floor and casting bed for heavy work. The drying stoves and dressing shop should be located within short range of the furnaces, and opposite them may be situated a large heating furnace for dealing with large scrap which requires to be broken before charging into the air furnaces.

Moulding machines are now almost universally used for small duplicate work, and are chiefly of the stripping-plate variety. For heavier work plate moulding is now very general, the pattern being made in several parts which can be fixed on the plates. The moulding boxes are lowered over these, rammed up, finished, and thoroughly dried in the stoves. For cleaning up the moulds, compressed air is highly advantageous, and should wherever possible be led to every part of the foundry; it is certainly much more efficacious than the old-fashioned bellows. The stove accommodation for drying large and small moulds must be very extensive. A form of double stove is manufactured which is fired from the side by char fires. Smaller stoves must also be provided for the drying of cores, the heating in this case may be done either by gas or char fires.

Whilst as a general rule it is advisable to carry out the casting of large work in dry sand moulds it is permissible to execute most of the small work in green sand. Sands which have stood the test of long service for this work are "Erith" and "Scotch Rock," the latter being largely used for dry sand work, the Erith being highly suitable for green sand moulding. For facings, it is customary to use good blacking in the dry sand moulds, but more often the green sand work is dusted with plumbago or terra-flake. Large barrel cores are made up of loam and straw, and for small intricate cores a mixture of finer sand with molasses and flour gives good results, being strongly binding, porous, and easily removed.

Each main bay should be served with at least one overhead electric crane, capable of rapidly lifting and transporting the heaviest moulds to be dealt with, and they can also be made to handle the large ladles used for heavy casts. Side bays can be fitted with small overhead hand cranes, as well as hydraulic cranes to operate smaller work and aid in the lifting-out operation at the pot fires. For transporting metal, small moulds and finished castings, a narrow-gauge tramway should be led throughout the shops, and the bogies run on this may be made to serve other useful purposes. For cutting, riddling and mixing sand, electric appliances are largely in vogue, and possess special advantages in dealing with large quantities.

In working the crucible furnaces, it is convenient to have the charges carefully weighed out and stacked at each fire ready for charging and melting. By suitably arranging the draught so as to get as complete combustion of the coke as possible, a good melter is able to take off at least four 160-lb. heats from each of nine furnaces in a working day of $9\frac{3}{4}$ hours, and those working with 240-lb. pots should be able to get out at least three melts from each of eight furnaces in the same time.

There are three important points to be taken into account in good melting practice: (1) The length of time the metal is in the furnace; (2) the character of the covering or flux; and (3) the temperature of melting and casting. The time of a melt depends chiefly on the weight of the charge, and with a bright fire it should be kept as short as possible consistent with the complete fusion and mixing of the constituents, as prolonged "stewing" only tends to increased absorption of gas, which causes blowholes when the metal solidifies. One of the best coverings for rich copper alloys is ground glass, which possesses the advantages of simplicity and cheapness, and this is generally more efficacious in protecting the molten metal than the so-called "patent" fluxes. When the pots are drawn and carefully skimmed, they are covered with a circular iron lid with a small pouring opening, and this saves most of the objectionable zinc fumes which would otherwise be given off copiously. The fuel used in melting is about 44 per cent. of the weight of metal.

The proportions of the charges for air furnaces are weighed out according to the composition of the alloy required, and the material is collected on the charging platform. The greater part of the charge being made up on the inclined bed of the furnace, the fire is started in the forenoon, and charging is completed by noon. With a 7-tons charge the metal is ready for tapping about five in the afternoon, when the requisite tin is added and after thorough rabbling and reheating, the charge is ready for tapping in another half-hour. It is found advisable not to draw all the metal off at one time, but to split

* Abstract of paper read before the British Foundrymen's Association Annual Convention, Cardiff, August, 1912.

the tap up into three lots of about 50 cwts. each, rabbling between each to minimise segregation. Prior to casting, the metal in the ladles should be carefully skimmed and covered with a layer of charcoal. The fuel consumption amounts to about 20 per cent. of the weight of the charge.

After the castings have been knocked out of the boxes they are then immediately run into the dressing shop, which

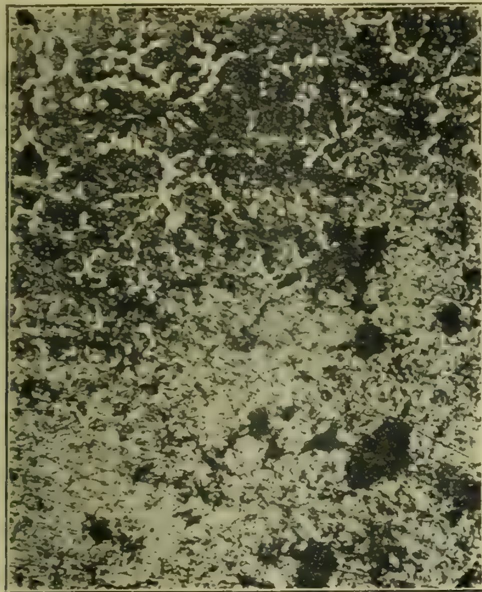


Fig. 2.—Microstructure of Gun-metal, showing Deep-seated Gas Holes. Magnified 60 Diameters.

should therefore be placed as near to the casting floor as possible. In addition to the ordinary hand tools, very useful fittings are heavy sprue cutters, bandsaws, pneumatic chipping hammers, and grinders. For an easy method of removing cores, and also for imparting a splendid finish to the castings, a sand-blast plant is almost a necessity. This plant has many advantages, and for large outputs has almost completely replaced the hand-dressing.

The large scrap from the dressing shop is generally clean, and consists of runners and fins from the castings, the pouring heads having been dealt with previously on the casting floor. This scrap can be sent back direct to the metal store and used over again in making up the furnace charges. It is an important economical consideration to systematically collect all the pot fire ashes, crucible furnace and ladle skimmings, as well as the dust from the dressing shop. Riddling recovers the larger pieces of metal, but it is advisable, especially with the furnace ashes, to crush these with water in a special form of inclined pan mill with heavy grinding balls. The metal is left in nodules in the pans, whilst the finely powdered ashes and small metallic particles are washed over and collected in a settler for subsequent sale. Such an arrangement is often accountable for a recovery of 25 per cent. of the weight of the ashes as valuable material. In cases where an engineering shop is connected with the foundry, it is highly advisable to keep the borings and turnings as clear as possible of iron and steel, and further to ensure complete removal of any chance contaminations by passing the metal through a suitable form of electro-magnetic separator.

For the accurate control of a brass foundry it is essential to have a well-equipped metallurgical and testing department, especially when the products have to conform closely to specification. Accurate knowledge of the allowances to be made in melting must be ascertained, and the amount of oxidation and volatilisation losses under the particular conditions of working must be determined in order to maintain a uniform composition of the resulting alloy. All scrap metal bought in should be melted, cast into ingots, and stacked in lots according to its analyses. The best results are only obtainable by making up the proportions of the charge constituents from the laboratory analysis, and in order to keep a thorough check on the resulting melts it is advisable to have these analysed also. All raw material, such as copper, tin, zinc, scrap, &c., should be bought to analysis, and carefully checked on delivery to ensure that it conforms to the specification. Where it is not possible to purchase on this basis, the material ought to be carefully analysed, and mixed accordingly.

The cost price of an alloy is largely determined by the price of the component parts, and when these differ considerably in value, even a slight variation in the alloy composition increases its cost. With copper at 6d. per pound, and tin at 1s. 8d. per pound, a true gun-metal of 90/10 composition would work out at 61s. 8d. per 100lbs., but if, by mixing anything other than pure metals without knowing the analysis the tin content is increased to 11 per cent. then the resulting alloy would cost 62s. 10d. per 100lbs. Such a variation may quite easily occur in practice which is not controlled by chemical analysis, and for a melt of 20 tons per week the loss would amount to £26, which is equivalent to £1,350 per annum. It is evident that in this and similar cases the cost of chemical control soon pays for itself several times over.

Another fruitful source of loss in a brass foundry is the copper carried by the refuse of various kinds, such as ashes, skimmings, floor sweepings, broken crucibles, &c. It is not always possible to erect plant in a foundry to recover the metallic portion of this waste, but it is certainly advantageous to dispose of it according to the copper content as determined by sampling and chemical analysis, and thus obtain a proper value for the material.

The most important physical testing to be done is with the cast metal in order to ascertain if it is up to the standard required, and sometimes this is able to detect material which, although correct in chemical composition, is faulty in structure and therefore unsuited for service. When such tests show results, the fracture may reveal a possible source of the trouble, but in many cases it does not, in which case it is necessary to adopt some other method of investigation.

In addition to the physical tests of the alloys, it pays to make examination of the various refractory materials, such as firebricks and fireclay, used in the furnaces. Also the various moulding and core sands should be tested, besides by analysis, for fineness, binding qualities, refractory properties, and porosity. Crucibles are an important item of expense, and every batch ought to be tested for strength and durability. The plumbago and blacking used for facings often cause trouble in practice unless carefully tested for impurities as well as volatile matter, ash and carbon content. It is important to keep a check upon the heating power of the fuel used, and the coke used must be one low in sulphur and ash, and not addicted to clinkering.

Within the last few years great progress has been made in the examination of the microstructure of alloys, and this

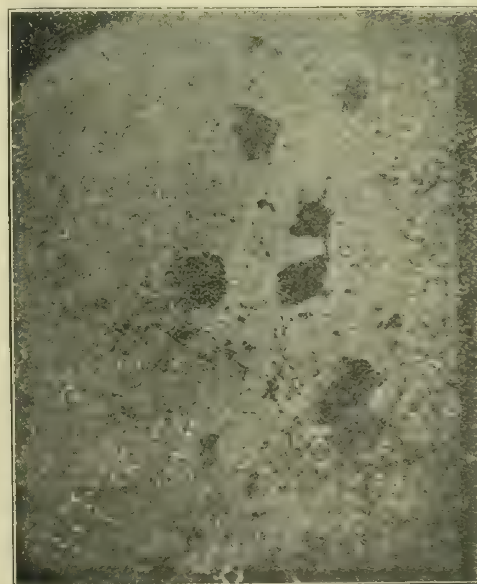


Fig. 3.—Microstructure of Gun-metal, showing Steam Holes near Surface. Magnified 30 Diameters.

science of metallography is becoming a most valuable aid to the foundry metallurgist. It is rapidly replacing the older method of judging by fracture, and is without doubt a more certain guide to the foundryman who wishes to escape the

repetition of serious failures due to causes other than change of chemical composition.

The temperature of melting and pouring has a great influence on the strength of gun-metal castings. The chief cause for the variations which occur in the quality of the metal is the different rates of cooling through the molten condition and complete solidification. By pouring at a suitably high temperature, which depends upon the work in hand, the sand of the mould becomes highly heated, so that the freezing of the metal is slower than if the metal is cast "dull," and hence the crystals have time to grow into a good strong interlocking structure. This formation is well shown in Fig. 1, which is the photo-micrograph of an Admiralty gun-metal test bar from a casting poured at the temperature of 1,100° C., and slowly cooled. The tensile strength of this was 16 tons per square inch with a 24 per cent. elongation on 2in.

Blow holes are often troublesome in gun-metal castings and very materially reduce the strength. They may be due to a variety of causes, amongst which are dampness in the mould, gases either entrapped in the mould or dissolved in the metal, and metallic oxides partly dissolved or mechanically mixed with the metal. They are often so small as to escape detection unless under the microscope, and this examination most clearly reveals their distribution and the most probable source

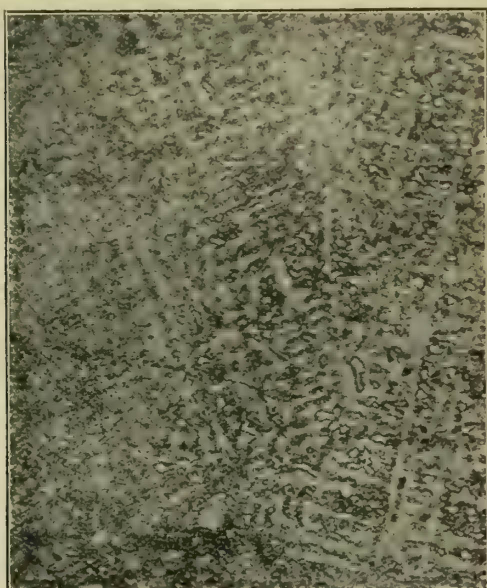


FIG 4.—MICROSTRUCTURE OF GOOD GUN-METAL, SAME AS IN FIG. 3, REMELTED. Magnified 60 Diameters.

of the trouble. When this is known, the remedy is easily found. Fig. 2 shows one type of blow hole deep seated in the metal, and evidently due to gas inclusions, which leave the cavities quite clean but so destroy the continuity of the structure that the interlocking of the crystals is diminished and the tensile strength much lowered, even though, as in this case, the chemical composition be right and the metal properly cast.

When the blow holes are sharply defined but confined to the outer portions of the casting, they are more likely to be due to steam generated within the mould, and this produces a local chilling which completely alters the structure, as seen in Fig. 3. This is the microstructure of a casting of perfectly satisfactory gun-metal by analysis, but which in this condition only stood a tensile strain of 5 tons per square inch. A simple remelting was sufficient to bring this metal right, and Fig. 4 shows the improved structure brought about in this way; the tensile strength being in this way increased to 16 tons per square inch.

The pyrometer is of great service in determining the temperature of the metal before pouring, but it is not practicable to observe the rate of cooling of each casting and attempt to regulate it. As gun-metal cools from fusion it passes through three distinct stages before it reaches normal temperature. In the first place a solid solution of copper with a little tin in it separates out, and this is known as alpha (α) constituent, which is soft and ductile. As further cooling takes place the remainder of the metal solidifies as a second constituent which is a solid solution of copper containing a larger amount of tin, and this is known as the beta (β) constituent. The alloy is now completely solid and consists of primary crystallites of alpha with areas of beta in the interstices. The beta constituent, however, is not stable, and as the temperature falls to about 500° C., it breaks up into a mixture of alpha con-

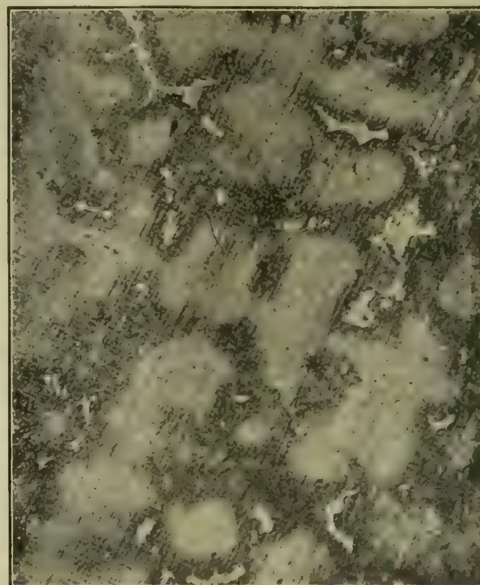


FIG. 5.—MICROSTRUCTURE OF GOOD GUN-METAL, SHOWING ISOLATED EUTECTIC AREAS. Magnified 240 Diameters.

stituent and delta (δ) constituent, which is a compound of copper and tin, having the formula Cu_4Sn. This is rich in tin (about 33 per cent.) and corresponds very closely to speculum metal, which accounts for its hard, brittle nature. The alloy is stable at ordinary temperature and now consists of a mixture of primary alpha crystallites, darker-etching littoral zones of the same constituent, in which is embedded the hard delta constituent which forms a eutectic structure with the secondary alpha, and remains white on etching. Such a normal structure got on slowly cooling a gun-metal casting is shown in Fig. 5, and illustrates the uniform distribution of the white eutectic areas, completely surrounded by the soft alpha constituent. A test bar cut from this metal stood 16 tons

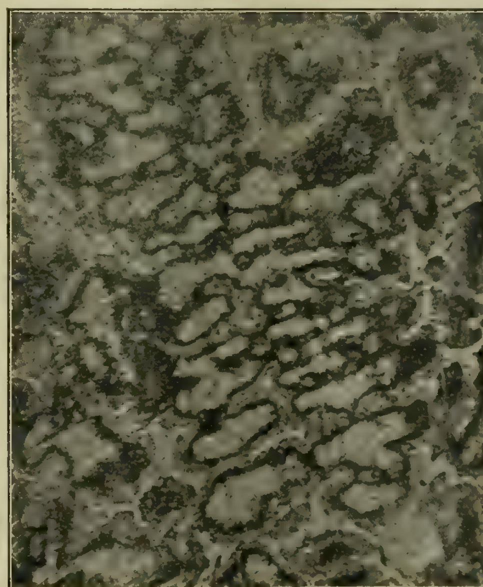


FIG. 6.—MICROSTRUCTURE OF GUN-METAL, SHOWING BRITTLE ARRANGEMENT OF EUTECTIC AREAS. Magnified 240 Diameters.

tensile strength, and showed an elongation of 24 per cent. on 2in. For comparison, Fig. 6 is reproduced to show how improper cooling can diminish the primary crystallites of alpha constituent, and cause it to be almost surrounded by the white eutectic areas. The physical tests of this material showed little diminution in the tensile strength, but the

elongation was very adversely affected, being only 9 per cent. on 2in.

The enormous value of the microscopical examination must be clear from even these few examples, and in the last-quoted case it suggests that a remedy for the low elongation results could be found by a suitable annealing of the metal above the temperature of 500° C., in order to promote the growth of the primary alpha crystallites and the absorption or balling-up of the eutectic areas into a uniform and less harmful distribution. In fact, the more completely these eutectiferous areas can be removed, the better the alloy becomes, and without doubt the correct solution of most of the common corrosion troubles lies in the direction of completely eliminating the eutectic from the alloy.

The author takes this opportunity of expressing his thanks to Messrs. G. & J. Weir, Ltd., of Cathcart, for their kind permission to publish these observations, as well as the photomicrographs made in the course of testing.

APPENDIX I.—*Example of a 7-ton Air-furnace Charge Sheet.*

Cast No. 721.

Date, June 3rd, 1912. Charge of No. 1 Admiralty Gun metal.

Charge.		Copper.		Tin.		Zinc.		Lead.	
Material.	Weight. Cwts.	Per Cent.	Cwts. Per Cent.	Per Cent.	Cwts. Per Cent.	Per Cent.	Cwts. Per Cent.	Per Cent.	Cwts. Per Cent.
Shop scrap	20	87·8	1,756	9·5	180	2·0	40	0·7	14
Bought-in scrap ...	59	85·5	5,044	8·5	501	5·0	295	1·0	59
Machine borings ...	20	87·7	1,754	9·5	180	2·0	40	0·8	16
Copper ingots ...	36	100·0	3,600	—	—	—	—	—	—
Tin ingots	5	—	—	100·0	500	—	—	—	—
Total	140	—	12,154	—	1,361	—	375	—	89
Average (calculated analysis)		87·0	—	9·7	—	2·7	—	0·63	—
(Actual analysis)		87·9	—	9·5	—	2·0	—	0·60	—

Physical Tests.

Bar No.	Diameter. Inches.	C.S.A. Sq. In.	Tons.	Tons per Sq. In.	Elongation. On 2in.	Elongation. Per Cent.
					In.	
1.	51/64	0·5	8·1	16·2	0·48	24·0
2.	,,	0·5	8·3	16·6	0·44	22·0

Remarks.

Condition of Metal.—Clean and hot, cast about 1,100° C. Three taps, each about 50 cwts.

Time of Melting.—Charged, 10 a.m. to 12 noon; tapped, 4-30 p.m.—6½ hours.

Fuel Consumption.—30 cwts. (Splint coal).

APPENDIX II.

Specification of Admiralty Gun-metal.

Composition.—Tin, 10 per cent.; zinc (max.), 2 per cent.; copper, remainder; impurities, nil. All copper is to be of approved quality. A deviation of more than 1 per cent. in the specified composition is sufficient to condemn the material.

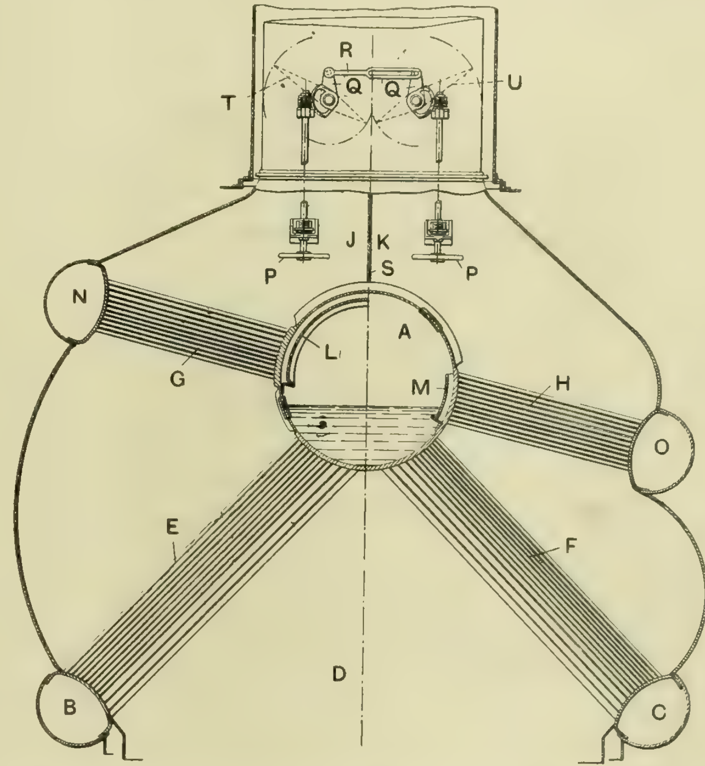
Tensile Tests.—The test pieces taken from the casting have to stand the following tests: Ultimate strength, not less than 14 tons per square inch; elongation on 2in., not less than 7·5 per cent.

General.—The castings are to be sound, clean, and free from blow holes.

YARROW'S WATER-TUBE BOILER FITTED WITH SUPERHEATER AND FEED HEATER.

A COMPACT arrangement of water-tube boiler superheater and feed-water heater, in which the tubes are all straight, has been patented by Mr. A. F. Yarrow, Campsie Dene, Blanefield, Stirling, Scotland. The arrangement is illustrated in transverse section in the accompanying illustration, in which A is the steam and water drum, B, C the two water drums, one on each side of the furnace D and connected by generator tubes E, F respectively with the steam drum A; G is the superheater and H the feed-water heater, L and M being longitudinal baffles in the steam and water drum A, one opposite the ends of the superheater tubes and extending upwardly to the top of the steam drum, and the other opposite the ends of the feed-water heater tubes. In order that the superheater and feed-water heater tubes G, H may be straight or substantially so and yet meet the wall of the steam drum A in a substantially radial direction, and also to avoid increasing unduly the width of the boiler while securing sufficient length of superheater and feed-heater tubes, the two banks of tubes are disposed, as shown, viz., with the collector N of the superheater about as much above the centre of the steam drum as the feed-water pocket or drum O is below the centre. With this disposition also and using straight tubes, the ends of the superheater tubes G are expanded into the wall of the steam drum about and above the normal water level in the steam drum, while the feed-heater tubes are expanded into the wall of the drum A about and below the normal water level.

When it is desired to make provision for using either the whole boiler or either half only of the boiler at will, a plate S, extending longitudinally above the steam and water drum A along the whole length of the boiler, divides the uptake



YARROW'S WATER-TUBE BOILER FITTED WITH SUPERHEATER AND FEED HEATER.

into two parts, J, K, the furnace gases which traverse the tubes E, G passing upwards through uptake J, and the gases which traverse the tubes F, H passing through uptake K. These uptakes are provided with dampers T, U respectively mounted to rotate upon horizontal axles, each provided with a quadrant rack. These racks are rotatable by means of pinions or worms carried upon spindles journalled in brackets at the end of the boiler and rotatable by means of the hand wheels P. The damper axles have arms Q rigid therewith, and these arms are coupled by means of a link R, which is connected pivotally with one arm and through a pin and slot connection with the other arm. The link R and slot are of such lengths that the dampers T, U cannot both be completely closed at the same time, while they may be both completely open at the same time, or either of them partially or completely open while the other is completely or partially closed.

Another Aviator Killed.—Mr. R. C. Fenwick, engaged in the military aeroplane tests at Larkhill Camp, Salisbury Plain, was killed on the 13th inst. as the result of a fall from his machine. It is supposed that a sudden gust of wind overbalanced the monoplane, which is a very small machine, while it was flying at a height of two or three hundred feet. It fell like a stone and was dashed to pieces. The aviator was killed instantly.

BOILER ECONOMICS AND THE USE OF HIGH GAS SPEEDS.*

BY J. T. NICOLSON.

PART I.—INTRODUCTORY.

IN a lecture delivered by the author in January, 1909,† experimental evidence was brought forward to prove that the amount of heat transferred from hot air to a metal surface is almost in direct proportion to the difference of their temperatures and to the product of the speed of movement and density of the air. This law was enunciated for fluids generally in 1874 by Prof. Osborne Reynolds, as a result of the then recently discovered kinetic theory of matter, but without serious experimental proof. That the law held for water on opposite sides of a metal wall was demonstrated in 1897 ‡ by Dr. T. E. Stanton, a pupil of Prof. Osborne Reynolds. In the same year Prof. John Perry attacked the subject in his book on the "Steam Engine," and showed, in striking fashion, what great improvements might be expected in boiler practice if Prof. Osborne Reynolds' views were correct and could be embodied in actual steam generating plants. The first opportunity for making experiments on the laws of heat transference from gases to liquids across a metal wall under high speed conditions, took place in the early part of 1905, when an apparatus was constructed at the works of Messrs. Joseph Adamson & Co., for cooling compressed air flowing through a pipe by means of a counter-flowing current of cold water. Further experiments with air and superheated steam were made by the author and by his pupil, Mr. (now Prof.) H. P. Jordan,§ at the Manchester Municipal School of Technology during 1906 and 1907. Finally, during 1908 and 1909, the author constructed an experimental boiler to test the validity of Prof. Osborne Reynolds' law when applied to the actual products of combustion; and in October, 1909, Mr. Michael Longridge conducted trials extending over six days upon this plant. The object of the present paper is to give some account of the results obtained with this experimental boiler, and to deduce the bearing of the newly obtained data upon boiler practice.

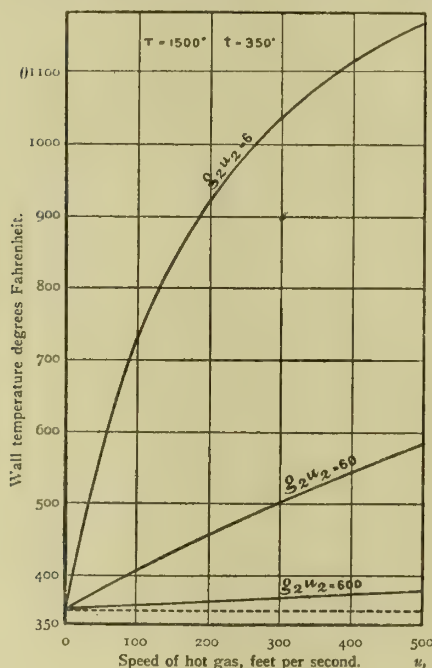


FIG. 1.

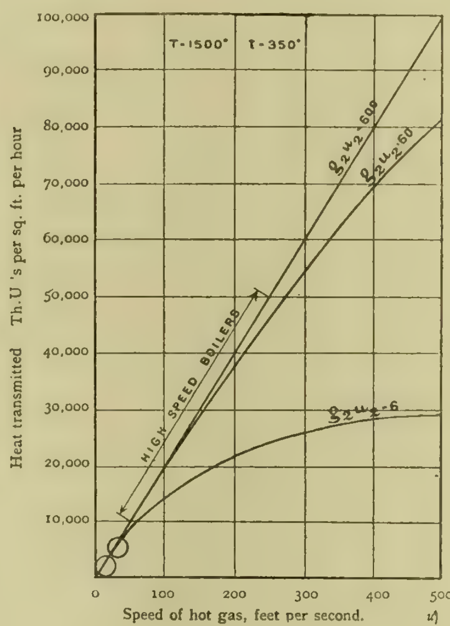


FIG. 2.

In the paper above referred to, the author gave Prof. Osborne Reynolds' formula for the rate of heat transmission from gas to plate in a somewhat elaborate form.‖ He had found from an examination of many boiler experiments, and from the experiments with compressed air and superheated steam which he himself had carried out, that the rate of heat transmission depended not only on the speed-density product, but also to some extent on the average value of the gas and wall temperatures, on the diameter, or, rather the hydraulic mean depth, of the pipes or flues through which the gas is flowing, and upon the nature of the metal surface in contact with the gas.

The author has reason to believe that the expression referred to gives a good first approximation to the true law, and that it holds for nearly all the varied conditions of heat transmission which are met with in practice; but it is of too complex a form for use in cases where varying gas and water temperatures render integration necessary. It appears preferable for the purposes of boiler design to make allowances, once for all, for these factors to suit each type of boiler, or to meet the different conditions in each part of a given boiler, so that a simple expression for the heat flow depending only on the gas density and speed and the temperature difference between the gas and plate may be employed. Such a formula is:—

$$Q = c_1 p_1 u_1 (T - \theta) \quad . \quad . \quad . \quad . \quad . \quad (2)$$

in which the value for the constant may vary at most from 3 to 6. Similarly for the flow from plate to water, Dr. Stanton's experiments have shown that:—

$$Q_2 = c_2 p_2 u_2 (\theta - t) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where c_2 does not vary much from 6. The physical results of different values of the ratio of p_2u_2 to p_1u_1 in these two formulæ are best understood by an examination of the diagrams given in Figs. 1 and 2. The former figure shows how the wall temperature varies as the gas speed increases with different rates of water circulation, the gas temperature remaining at 1,500° Fah., and the water at 350° Fah. The latter figure gives roughly the amounts of heat which can be transmitted for the three water speeds of 10ft., 1ft., and 0·1ft. per second, whilst the gas speed increases up to 500ft. per second.

In Fig. 2 the circles near the origin show the region in which present-day boilers usually work; the gas speeds being from 10ft. to 30ft. per second, and the heat transmissions from 2,000 to 8,000 thermal units per square foot per hour. The dimension line on the same figure shows the region in which, according to the author, they should be made to work, namely, with gas speeds up to 250ft. per second, and heat transmissions up to 40 or 50 thousand units per square foot per hour. The latter figure has already been reached by the author in the experimental boiler trials made by Mr. Michael Longridge. To these further reference will be made in the appropriate place. Applying such a formula to the case of an ordinary smoke-tube boiler, it is easy to calculate the chimney temperature, if the firebox temperature is known. The curious fact then appears that the drop of temperature between firebox and smokebox does not at all depend upon the mere magnitude of the heating surface, as is usually supposed; but only upon the ratio of the length of the tubes to their diameter, or, what is the same thing, the ratio of the total area of heating surface to the cross-sectional area of all the tubes or flues for gas. In fact, the chimney temperature for a given constant furnace temperature remains the same whether a boiler has 500 tubes or only 100, provided the water circulation is properly attended to. Thus it will be seen that, if it be possible to force the gases through the smaller area, a boiler of correspondingly smaller heating surface, weight, and cost can be constructed to give the same efficiency of heat transmission as before. A considerable drop of pressure, owing to hydraulic resistance, takes place in the gas between firebox and smokebox when the products are forced through such narrow flues at a high speed; and the first cost and running expenses of an exhausting fan of greater or less power have to be incurred to do the work. This is the per contra to be faced when the endeavour is made to design a boiler of the smaller size and weight here contemplated. The problem under consideration is to find how far it will pay to go in the direction of increase of the gas speed through the flues of a boiler, and to see whether the design of the steam generator, as now made, cannot be improved by the use of a powerful draught, a high

* Paper read before the Institution of Engineers and Shipbuilders of Scotland.
† Trans. Junior Inst. of Eng. Vol. XIX., February, 1909.
‡ Trans. Royal Society, Vol. CXCIX., pp. 67 88 (1897).
§ Trans. Junior Inst. Eng. p. 236, February, 1909.
‖ Proc. Inst. Mech. Eng., p. 1,012, October, 1909

gas speed, and a smaller heating surface. At first it may appear that this is a mere restatement of the old problem of forced or induced draught and its best intensity—a problem which seems to have been solved in practice by restricting the pressure difference to such moderate values as 3in. or 4in. of water gauge between ashpit and chimney.

There is, however, a fundamental difference between the system now proposed and all other forced or induced draught systems. It lies in the fact that the high draughts employed do not necessarily involve high rates of combustion on the grate. No matter how great the difference of air pressure between furnace and funnel may be, that between furnace and ashpit need not, and preferably should not, be greater than what is commonly employed when firing under "natural" draught! It may, for example, be found that, for a certain type of boiler a vacuum of 20in. of water at the fan suction gives, on the whole, the most economical results, whilst, at the same time, it will appear that the rate of firing should be limited to such moderate amounts as 25lbs. or 30lbs. of coal per hour per square foot of grate surface. In such a case almost the whole of the 20in. of draught is spent upon drawing the gases through the flues at high speed, in the evaporating and economising portions of the boiler; whereas, with the systems hitherto used the greatest resistance to the passage of the gas has always been offered by the fire itself, and a high blast meant a thick fire and a high rate of firing. It will probably be admitted by all engineers as axiomatic that, up to the present time, when forced or induced draughts have been made use of, a high rate of combustion has always been contemplated as part of the system. It is well known that with such forced combustion, a smaller air supply and a hotter fire is obtained. The heat radiated to the furnace crown from the fire, and the heat given up by the gases to the plates and tubes are consequently both increased by this means, and a considerably greater evaporative power is possible from a boiler using forced firing. Not only so; but it has been found that notwithstanding the higher chimney temperatures which, in accordance with what has already been stated, result from the rise of the furnace temperature under forced draught, the amount of heat finally lost in the waste gases is actually reduced when the fire is forced.

Why, then, it may well be asked, have engineers stopped short with such moderate draughts as those indicated above—draughts which, as many will recall, are much smaller than what were quite commonly in use 15 or 20 years ago, more especially in the Royal Navy, and which are now daily in use on locomotives. The answer given by most engineers would probably be that troubles due to overheating and leaking tube ends had had a good deal to do with the matter; but the author suggests that this can hardly be the true cause for high draughts having ceased to be the fashion, because there is really no difficulty with water-tube boilers of the Yarrow or Thornycroft types (or any type of boiler with a really rapid water circulation) in entirely preventing injury to the tubes even when the fires are forced to any possible extent, so that evaporations of 40 or more pounds of steam per square foot per hour are attained. The real reason, and one which the author ventures to think has not been very generally appreciated, is connected with the ultimate economy of the system.

It has been found that very powerful draughts accompanied, as described, by high rates of combustion, do not prove to be economical; and the author proposes now to try and show that the high rates have been abandoned because the heat losses incurred in the furnace more than discount the diminished chimney loss, the reduced heating surfaces, and lighter boilers which they rendered possible, and a reactionary era of moderate draughts, for naval and marine work, and even of natural or chimney draught for land work, has, in consequence, set in. The object in reading this paper is to maintain that this is a retrograde step, and that the design of a steam generating plant on rational lines will lead not only to a return to the high (forced or induced) draughts which were formerly in vogue, but even to draughts three or four times as great as had ever yet been attempted.

In elucidating the matter, it will be well, first, to take up the problem of the furnace, and to show in what way the total efficiency of the boiler is finally reduced by increasing the rate of firing. Then, taking up the question of heat transmission from gas to water, to endeavour to show what has been, and can be, done by means of a high blast, with its accompanying great velocity of gas flow, in reducing the area of the heating surface necessary for a given power, without, at the same time, diminishing the net efficiency of the system.

Finally, the author will consider the matter of the total annual cost to the user of the generation of a given quantity of steam for power purposes, and, having reduced the various items to a series of curves of cost on a base of gas velocity, or, what is the same thing, of draught pressure, he will ask whether he has not proved the proposition that (at all events for naval and marine purposes, and for power stations, where space was valuable) a much higher draught pressure should be resorted to than had hitherto been usual.

PART II.—FURNACE AND CHIMNEY LOSSES, AND THE MOST EFFICIENT RATE OF COMBUSTION.

In all ordinary boilers there are two chief sources of loss of efficiency. They are, first, furnace loss; second, chimney loss. Furnace loss is that fraction of the total heat in the coal which goes to waste on account of the imperfect combustion or the non-combustion of parts of its constituents. Chimney loss is that fraction of the coal heat which goes to waste by reason of the products of combustion leaving the boiler at temperatures higher than that of the entering feed.

Furnace Loss.—It is well known that in every boiler furnace a certain proportion of the coal, greater or smaller, is not completely burned to carbon dioxide, but is only partially burnt to carbon monoxide. It also frequently happens that quantities of hydrogen, marsh gas, and other hydrocarbons escape from the boiler, wholly or partially unburnt. It is also known that these actions are much more likely to take place with high rates of firing than with low. With heavy firing the fires are much thicker, less air is supplied per pound of coal, and there is, accordingly, less chance of that intimate mixture of the fuel and the air which is necessary to avoid the escape of unburnt gas. But the chief source of loss in the furnace is the blowing out of the fire of coal dust and small coal, which is carried right through the flues without being burnt, and goes away up the chimney. At low rates only very fine dust escapes in this way, and the action is possibly unimportant; but with the fierce blast of a locomotive running at full speed (10in. water gauge or more), there is a constant rain of quite large pieces of coal from the top of the funnel, and by far the greatest proportion of all the loss incurred in the furnace is due to this cause.

The papers recently read in London by Mr. Brislee and Mr. Lawford Fry have emphasized this matter, and from the figures and diagrams given by them the author finds that a roughly correct law he had previously deduced from the French experiments may be used here, namely, that the combined loss of heat due to imperfect combustion and coal blown

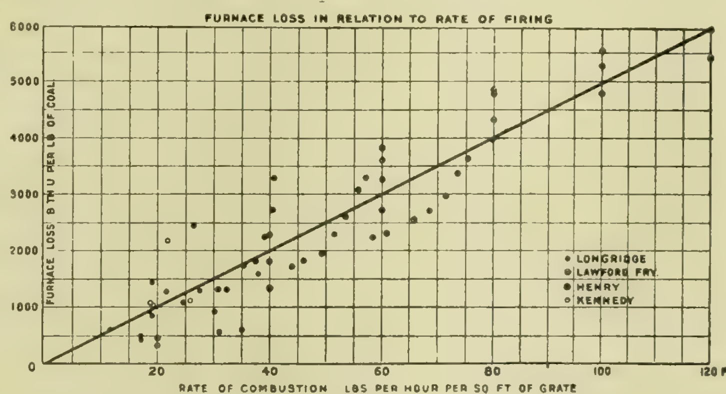


FIG. 2A.

away amounts to 50 F.Th.U. per pound of coal; where F is the rate of firing in pounds of coal per square foot of grate per hour. Thus, if Q denotes the calorific value of the coal used, then the heat actually generated in the fire is—

$$Q_0 = Q - 50 \text{ F.Th.U. per lb. of coal} \quad . \quad . \quad (4)$$

In boilers of ordinary design this 50 F is a total loss, the unburnt gases and small coal being carried away to the chimney without making any further addition of heat to the products of combustion. In Figs. 3 and 4 this loss has been plotted and marked "furnace loss"; but the author has there used a slightly more complex expression for the loss which he believes to be more correct, namely—

$$Q_0 = Q - (500 + 50F) \quad . \quad . \quad . \quad . \quad . \quad (5)$$

The additional term is intended to cover the loss caused by droppings into the ashpit, and other slight losses, which occur in all cases whatever the rate of firing. (See also Table I.)

Chimney Loss.—The evaluation of this loss in thermal units is got very simply by multiplying the thermal capacity of the weight of gas produced by 1lb. of coal by the difference between the chimney and ashpit temperatures. Thus chimney loss equals—

$$k_p\ (A+1)\ (T_3 - 60°)\ \text{Th.U. per lb. of coal} \quad . \quad . \quad (6)$$

Here A = weight of air supplied per lb. of coal (lbs.).

k_p = specific heat of products.

T_3 = chimney temperature of gases (Fah.).

60° = " ashpit " or entering air temperature (Fah.).

Obviously, T_3, the chimney temperature, must be known in order to determine this loss; and it is well known that the temperature at the base of the chimney rises and falls to a certain extent with the rise and fall of the furnace temperature. By a formula deduced elsewhere it is shown that—

$$\frac{s}{a} = c \log_\epsilon \frac{T_1 - t}{T_3 - t} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$\text{or } \epsilon^{\frac{s}{ca}} = \frac{T_1 - t}{T_3 - t} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7\text{A})$$

where s = area of heating surface in square feet.

a = cross-sectional area of flue in square feet.

T_1 = furnace, T_3 = chimney, t = steam } temperatures.

Hence :—

$$T_3 = t\left(1 - \epsilon^{-\frac{s}{ca}}\right) + T_1\epsilon^{-\frac{s}{ca}} = A + BT_1 \quad . \quad . \quad . \quad (8)$$

from which it will be seen that, for a boiler of given " surface-section ratio," the chimney temperature is a linear function

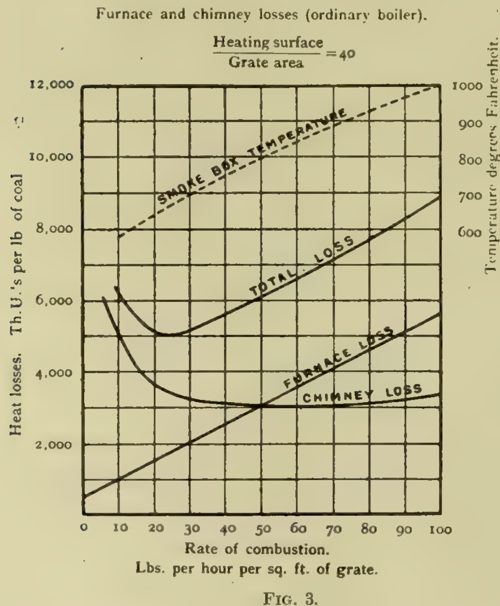


FIG. 3.

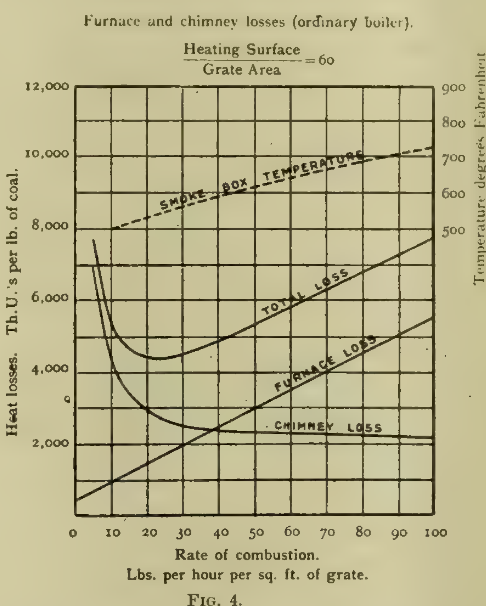


FIG. 4.

of the furnace temperature, increasing and diminishing therewith.

Furnace Temperature.—It is now necessary to find the furnace temperature as dependent upon the rate of combustion. The heat generated in the fire per square foot of grate is obviously Q_0F. This heat is disposed of in two ways :—

(1) By radiation from the fire surface to the furnace plates.

(2) By heat communicated to the products of combustion, their temperature being thereby raised from 60° to T_0.

By Stefan and Boltzmann's law of radiation the quantity of heat radiated per hour per square foot of fire surface is—

$$R = 1600\left(\frac{\tau_0}{1000}\right)^4 \text{Th.U.} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Where $\tau_0 = T_0 + 461$, the absolute temperature of the fire surface. The heat received by the furnace gases per square foot of grate per hour is k_p (A + 1) F (T – 60). Therefore the heat equation for 1 sq. ft. of grate may be written as follows :—

$$(Q - 50F)\ F = 1600\left(\frac{\tau_0}{1000}\right)^4 + k_p(A + 1(F(\tau_0 - 521) \quad . \quad . \quad (10)$$

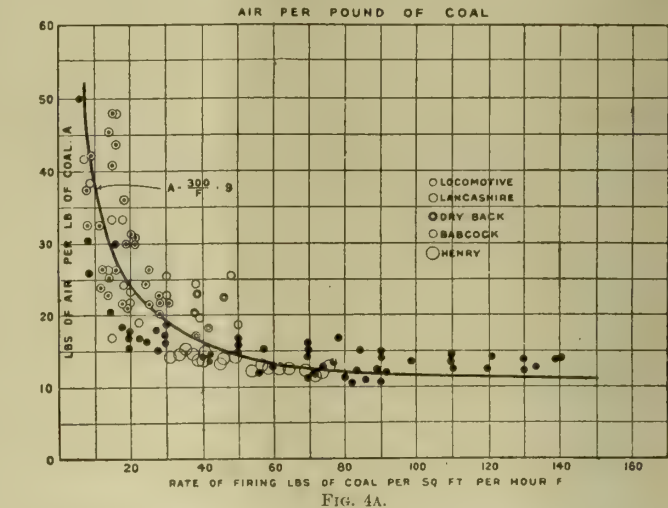


FIG. 4A.

From the study of many boiler trials the author has deduced as an expression for the amount of air supplied per pound of coal with good firing—

$$A = \frac{300}{F} + 9\text{lbs. per lb. of coal} \quad . \quad . \quad . \quad (11)$$

Substituting, therefore, in (10) for A + 1 the expression—

$$\frac{300}{F} + 10$$

the heat equation reduces to—

$$\left(\frac{\tau_0}{1000}\right)^4 + (46{\cdot}9) + 1563F\left(\frac{\tau_0}{1000}\right) = \frac{Q - 50F}{1600}F + 24{\cdot}4 + 0{\cdot}812F,$$

which is of the form—

$$x^4 + Bx + C = O \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10\text{B})$$

This can easily be solved by trial and error with a slide rule or graphically; and the values of τ_0 and T_0 so obtained have been written out in Table II., and plotted on Fig. 5.

It will be seen that the furnace temperature as thus determined rises very rapidly at first as F increases, reaches a maximum for F = 80, and then begins to fall. One ought to expect an increase of the furnace temperature with an increased rate of combustion, because less air is supplied per pound of coal, and there is, consequently, a smaller weight of products to be heated up. Recalling, however, the fact that the heat actually generated in the fire per pound of coal gets less and less, owing to imperfect combustion and coal dust blown away the harder one fires, it will readily appear that this source of loss will presently overtake the gain due to diminished air supply, the furnace temperature curve will rise less and less steeply, and will finally attain a maximum. It will afterwards fall. On the same diagram the observed furnace temperatures given by Mr. Lawford Fry have also been plotted, and a fair curve drawn through them.

TABLE I.—*Values of the Furnace Losses per Pound of Coal, with Different Rates of Firing.*

Calorific value of coal, Q = 14,500.

Th.U. F lbs.	10	20	30	40	60	80	100
50 F.	500	1,000	1,500	2,000	3,000	4,000	5,000
Q—50 F.	14,000	13,500	13,000	12,500	11,500	10,500	9,500
Q—(500 + 50 F).	13,500	13,000	12,500	12,000	11,000	10,000	9,000

The theoretically determined values, which lie well above those given by experiment, are believed by the author to be more nearly the true values of the furnace temperature than those given by the pyrometer. It is practically certain that all observed furnace temperatures taken by pyrometers are too low. It is almost impossible to perfectly shield the receiver of the pyrometer and prevent it from itself radiating away heat. Thus, it only records the temperature due to the difference between the radiation it receives and what it gives out. On Fig. 5 has also been plotted a curve of total radiation from the fire surface to the firebox, in thermal units per square foot of fire surface per hour, according to the law—

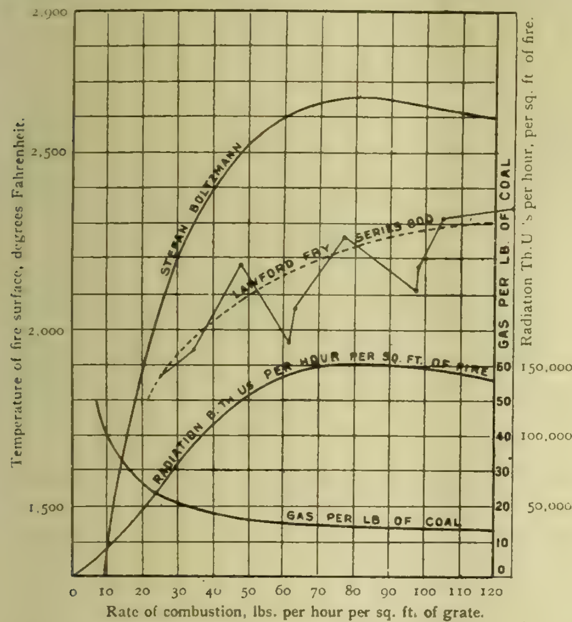


FIG. 5.

$$R = 1600 \left(\frac{\tau_0}{1000}\right)^4.$$

On the same figure it is also found a curve of the values of $A + 1 = \frac{300}{F} + 10$ the weight of the products of combustion per pound of coal with good ordinary hand firing. It is now easy to find T_3, the chimney temperature for the various given values of T_0 (or T_1) by equation (8). The results have been plotted on the Figs. 3 and 4 already referred to. Finally, by using expression (6), the chimney loss can be calculated, and, by adding it to the furnace loss, the whole loss of heat in the boiler due to these two causes together for various rates of firing may be found. The results are given in the annexed Table III., and plotted on Figs. 3 and 4.

In Fig. 6 the quantities under discussion have been re-plotted in order more clearly to bring their relationship to each other and to the total efficiency of the boiler into view. The line D E represents by its height above the base the calorific value (reckoned above 60° Fah.) of the coal used. The sloping dotted line D D shows the heat generated in the fire per pound of coal, $Q_0 = (Q - 50\,F)$; so that such an ordinate as *ed* represents the furnace loss (50 F) for F = 75. The dotted curve B B is set down from D D in such a way that any ordinate *db* represents the chimney loss (as already plotted on Fig. 3). Thus the whole height *oe*, representing the total heat in the coal, and the height *ed* + *db* − *eb* giving the sum of the furnace and chimney losses, it will be seen that the ordinate *ob* represents the total heat (per pound of coal) transferred to the water, of which *oa* is the fraction transferred by direct radiation, and *ab* that transmitted through the convective heating surface. Thus, the ratio $\frac{ob}{oe} = \tau$ is the boiler efficiency, and a scale marked on the right side of the figure measures this.

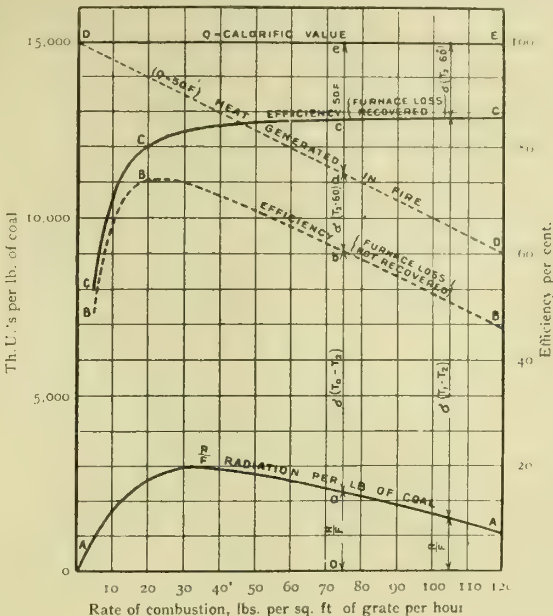


FIG. 6.

It is now clear from Figs. 3, 4, and 6 that the most efficient rate of firing occurs at between 25lbs. and 30lbs. of coal per square foot of grate per hour. For smaller values the combustion is more perfect, but the large chimney loss, due to the large amount of air supplied, more than makes up for this. For higher rates the chimney loss gets less, but imperfect combustion and dust blown out of the fire does away with the advantage. The temperature of the waste gases naturally depends on the length of the flues through which they pass, and in Figs. 3 and 4 the author has plotted these temperatures and the curves of furnace, chimney, and total loss for two different boilers, one having long tubes and the other short ones. It will be observed that there is very little difference in the value of the most economical rate of firing in the two cases. The minimum waste of heat, due to furnace and chimney loss combined, takes place in both boilers for a rate of firing somewhere between 20lbs. and 30lbs. per square foot of grate per hour.

PART III.—POSSIBILITY OF RECOVERY OF FURNACE LOSSES BY THE USE OF A REVERBERATORY CHAMBER.

BOILER-HEAT DIAGRAMS.

The correctness of this conclusion (which the author believes has not been previously pointed out) depends altogether on whether the furnace loss should be assumed to be a total loss or not. There can be no doubt that a loss of 50 F units of heat per pound of coal is caused in present-day furnaces, as ordinarily designed, when coal is burnt at the rate of F lbs. per square foot of grate per hour, and that this loss is not recovered at all. But the question arises: Is it not possible by means of a better construction to get back these losses due to unburnt gas and coal dust, by a process of after-burning in a reverberatory chamber, for example; so that the 50 F thermal units per pound of coal may be wholly or partially recovered, being returned as heat to the products in the reverberatory chamber, and so made available for transfer to the water? In this case the only loss would be

TABLE II.—*Fire Temperatures with Different Rates of Firing. Also Radiation per Square Foot of Fire per Hour and per Pound of Coal.*

Coal burnt per hour per sq. ft.	(F)	10	20	30	40	50	60	80	100	120
Fire temperature (abs.)	(τ_0)	1,810	2,360	2,665	2,860	2,980	3,070	3,125	3,100	3,060
Fire temperature Fah.	(T_0)	1,350	1,900	2,205	2,400	2,520	2,610	2,665	2,640	2,600
Radiation per hour per sq. ft. of fire surface	(R)	17,200	49,600	81,000	108,000	126,000	142,500	152,800	147,600	120,000
Radiation per pound of coal	$\left(\frac{R}{F}\right)$	1,720	2,480	2,700	2,700	2,520	2,375	1,910	1,476	1,000

that incurred by heat in the waste gases to the chimney. Referring again to Fig. 6, this state of affairs has been represented by drawing the efficiency curve C C. This curve is got by setting down the chimney loss from the line de of total coal heat. Thus ec $(=db)$ is the chimney loss for F = 75; co is the total heat transferred to water (of which oa is by radiation); and $\frac{oc}{oe}$ is the boiler efficiency. It will be observed that there is now no particular best rate of combustion. The greater that rate the smaller the chimney loss, and, therefore,

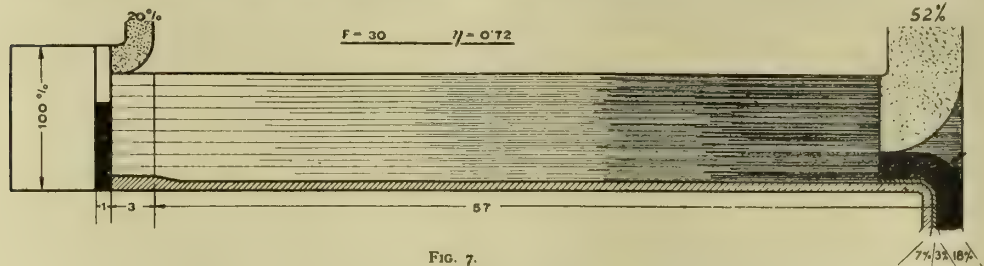


Fig. 7.

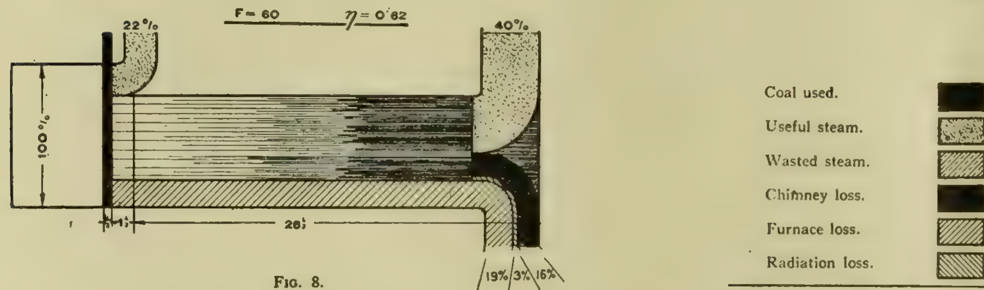


Fig. 8.

Table III.—*Values of Chimney Temperatures and Chimney Losses, as Plotted on Figs. 3 and 4.*

	F=	10	20	30	40	60	80	100
T_3	$\frac{S}{G}=40$	580° F.	650	700	750	805	895	1,000
	$\frac{S}{G}=60$	500° F.	535	565	590	645	690	730
$k_p(A+1)(T_3-60)$	(40)	5,300	3,750	3,300	3,150	3,100	3,200	3,360
	(60)	4,650	3,020	2,600	2,460	2,350	2,290	2,210

the higher the efficiency. In cases where some portion of the furnace loss (50 F) can be recovered by after-burning, the efficiency will have values intermediate to those of curves C C and B B. The matter will, the author thinks, be better elucidated by the use of certain diagrams, Figs. 7, 8, 9, and 10, showing the disposition of the heat available in the coal supplied to the boiler under the varying conditions here considered. In these diagrams the heights represent the amount of heat supplied; whilst horizontal distances represent the areas of the various heating surfaces. Thus, in Fig. 7, which refers to a Lancashire boiler, 57 means that the ratio of heating to grate surface is 57 to 1. The figure 3 represents the area of the furnace plating directly exposed to the radiant heat of the fire; and the dotted area marked 20 per cent. is the fraction of heat turned into steam by direct radiative evaporation. This quantity is known from the expression—

$$R = 1600\left(\frac{\tau_0}{1000}\right)^4 \text{Th.U.}$$

per square foot of fire-grate area per hour, which is the radiation from each square foot of fire surface, and can be calculated as soon as the furnace temperature has been found in the manner shown above. The ratio $\frac{R}{F\,Q}$ gives the required fraction of radiative evaporation.

The large proportion of all steam generated which is due to direct radiation from the fire is very striking. One can see the absurdity of lining the firebox itself with firebricks. It is by far the most powerful evaporating surface in any boiler of present-day design. The diagonally hatched strip marked 7 per cent. at the bottom of the diagram is the furnace loss which is not recovered, and goes away as waste. The black strip marked 18 per cent. is the chimney loss; and 3 per cent. has been allowed for external radiation. This leaves 52 per cent. for evaporation by the convective (as opposed to radiative) heating surface. The efficiency of the boiler is (20 + 52) 72 per cent.

Fig. 8 refers to a locomotive boiler of the same power as the Lancashire type. The rate of combustion is now double (F = 60) what it has been assumed for the Lancashire boiler; so that the grate area for the same power is but half. The ratios of firebox plate area and tube heating surface to grate area are taken the same as for the Lancashire boiler; but their actual values are only half of those for the Lancashire boiler. The boiler is forced so much more than that represented by Fig. 7 that nearly as great a total evaporation is obtained from only half the heating surface. On account of the greatly increased rate of firing, the furnace loss is now 19 per cent., and this loss goes right through the boiler tubes to waste. It is shown by the diagonally hatched strip at the bottom of the figure. The radiative evaporation is greater here than before, because the fire is hotter, notwithstanding the greater furnace loss. The total efficiency is marked as 62 per cent.—about 10 per cent. less than for the Lancashire boiler. This figure is smaller because, although the chimney loss is less, the furnace loss is greater than before on account of the doubled rate of firing.

The next boiler-heat diagram, Fig. 9, refers to an experimental boiler constructed by the author to test the effects of high gas speeds. The diagram represents the disposition of heat which the author hoped to secure; but, he is sorry to say, these results were not quite fully realised. He sees no reason, however, why they should not be obtained with a new plant designed in accordance with the data now gained. It will be seen that the heating surface per square foot of grate is here only about half what it was for the locomotive boiler, the coal burnt per square foot of grate being assumed the same. The furnace loss should therefore be the same; but it will be seen that it is supposed entirely to disappear by after-burning in a reverberatory or brick-lined combustion chamber placed beyond the firebridge; so that the furnace loss is eliminated, and a corresponding quantity of heat (19 per cent.) is rendered available for evaporation in the tubes. The chimney loss is greatly reduced also, being 4 per cent. instead of 16 per cent. in the locomotive. This is because the boiler was fitted with a counter current economiser, by means of which it was possible to lower the waste gas temperature to

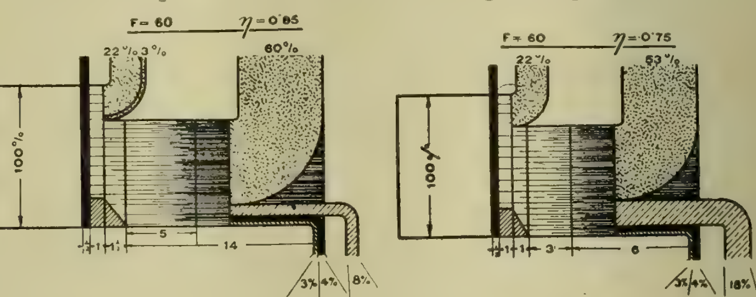


Fig. 9. Fig. 10.

170° Fah. when the feed entered at 60° Fah. The diagonally dotted line strip marked 8 per cent. is the loss incurred by the fan.

In order to secure such a small heating surface per unit of power developed, a powerful draught has to be employed, and 8 or 10 per cent. of the steam generated has to be spent to produce it. Notwithstanding this, it will be observed that the fan loss and chimney loss together amount only to 12 per cent., against the 16 per cent. of chimney loss alone in the locomotive type. Thus, allowing nothing at all in saving for the diminished furnace loss due to a reverberatory chamber, it appears to be possible to halve the heating surface of

a boiler by adopting a high gas speed and a counter current economiser, and yet to secure a higher efficiency than that ordinarily obtained.

The last diagram, Fig. 10, shows the similar relations which hold for a naval type boiler having a draught of 35in. of water gauge, and a correspondingly reduced heating surface. The author hopes shortly to be in a position to build and test such a boiler. The distinguishing features of the new designs depicted by Figs. 9 and 10 are seen to be: First, the provision of means for producing secondary combustion in a hot chamber (to which additional air is supplied) of the unburnt gas and coal dust escaping from the fire. Second, the use of a relatively very highly (forced or) induced draught, whereby the products of combustion are compelled to pass through narrow flues at a high speed, so that greatly enhanced rates of evaporation, and a much reduced area of heating surface are secured; and third, the use of a counterflow economiser whereby the gas temperatures are lowered to about 220° Fah., and the steam spent upon the fan plant is more than made up.

It will be observed as between Figs. 9 and 10 that as one attempts to diminish the heating surface the amount of steam wasted on the fan plant increases; and the main problem which it is attempted to evolve in this paper is the discovery of the most economical value of the draught pressure; that pressure, namely, for which the total annual cost of steam generation is a minimum.

It will now be fitting for the author to give some account of the means which he adopted to give effect to these principles. He therefore proceeds to give a short description of the successive experimental plants erected at Messrs. Joseph Adamson & Co.'s works, Hyde, and a history of the tests there made and the experiences obtained.

(To be continued.)

CORRESPONDENCE.

Continental Designs of Burners for Welding and Cutting Metals.

To the Editor of "The Mechanical Engineer."

Sir,—With reference to the above, we note in your article of August 2nd you state the following: "In the production of burners using liquid fuel, more economical thermally and less dangerous than acetylene burners," and we wish to point out that most thorough tests, carried out by two different authorities in Germany, have demonstrated that the use of liquid fuel for welding is clearly much more dangerous than the use of oxy-acetylene, costs considerably more in working, and gives less reliable welds. At the present moment we are having a translation of very exhaustive reports on this matter made, and will do ourselves the pleasure of sending you a copy shortly. Meanwhile, we shall be obliged if you will give publicity to this communication of ours.—Yours faithfully,

For Acetylene Publicity, Ltd.
Alec. D. Saville, Manager.

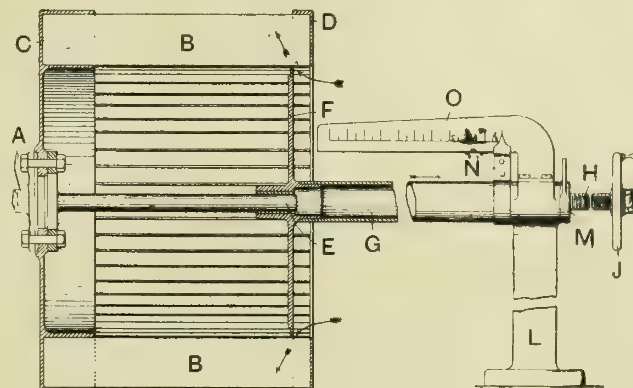
103 and 104, Cheapside, London, E.C.
August 7th, 1912.

Fatality to an Engineman.—A man named Simeon Williams, of Wombourne, met with a terrible death on Saturday, the 3rd inst., in his winding engine at Barrow Hill, Pensnett, belonging to the Earl of Dudley. In order to move the engine off "centre," Williams apparently stepped on to one of the arms of the driving wheel. He slipped and fell into the wheel hole. The wheel revolved and crushed him to death.

Bearing Tests.—A series of tests on the friction of bearings are in progress at the Manchester Technical School, under the direction of Prof. Nicolson. The tests are being undertaken with the object of determining the relative friction losses of various types of commercial bearings and to compare the total running costs. The apparatus employed consists of a shaft carrying heavy flywheels and supported by two similar bearings. It is run up to speed by a motor which is then thrown out of gear, the rate of slowing of the shaft being recorded automatically by a tachograph for a drop in speed of about 5 or 10 per cent. The clutch is then put in gear again and the test repeated. Practically all commercial forms of plain, ring oiling, needle lubricator, forced lubrication, ball and roller bearings will be dealt with.

WALKER'S ROTARY ABSORPTION DYNAMOMETER.

The accompanying illustration shows a design of rotary absorption dynamometer of the kind in which the volume of the medium passing through and acting on the dynamometer may be varied while the apparatus is in motion, for the purpose of varying the resistance offered by the dynamometer to the engine under test. The dynamometer, which is the invention of Mr. W. G. Walker, 2, Emery Hill Street, Westminster, S.W., comprises a centrifugal fan-wheel, the blades B of which are mounted upon a disc C and are braced by a ring D. The disc C is adapted to be coupled to the flanged extremity of the engine shaft A to be tested, and is provided with an axial guide spindle E. A regulating disc F is adapted to be travelled within and longitudinally of the fan-wheel and to this end the disc is mounted upon a tubular spindle G



Walker's Rotary Absorption Dynamometer.

carried by a screw-threaded rod H provided with an operating hand wheel J and working in a bearing supported upon a pedestal L adapted to be fixed firmly in any suitable position relatively to the dynamometer. A locking nut M serves to secure the screw-threaded rod H in any position of adjustment. The screw-threaded rod H or the tubular spindle G is provided with a pointer N adapted to be travelled when the hand wheel J is turned to adjust the disc F, over an arm O having a graduated scale. The regulating disc F is formed with a boss having a central aperture to take over the guide spindle E which thus supports the disc as it is travelled within the fan-wheel. The power absorbed by the dynamometer varies as the supply of air inhaled by the fan-wheel, and by sliding the regulating disc F more or less longitudinally within the fan-wheel the volume of the air supply can be varied. The path of the air supply is indicated by arrows.

In order that the horse-power absorbed by the dynamometer for each of a number of predetermined positions of the regulating disc relatively to the fan-wheel may be ascertained, the apparatus is calibrated. This calibration is effected by coupling the dynamometer to a prime mover of known horse-power and calculating in the known manner the horse-power absorbed by the dynamometer when the disc F is in various positions longitudinally of the fan-wheel. For each horse-power absorbed, the position of the disc F is recorded by engraving upon the arm O the corresponding position of the index N. In use the dynamometer is connected to the shaft A of the engine to be tested and the disc F is positioned within the fan-wheel by loosening the locking nut M and turning the hand wheel J and hence also the screw-threaded rod H. The disc F does not rotate with the fan-wheel but is slidden along the guide spindle E, and the greater the extent to which the disc F is moved into the fan-wheel the greater the volume of air supplied to and therefore the greater the resistance offered to the dynamometer. The greater also the horse-power absorbed by the dynamometer. Thus, by moving the disc F into the various predetermined positions as indicated on the arm O, each of which corresponds with a known unit of power absorption (or multiple thereof), the different observations necessary to effect the test of the engine may be taken and the results calculated in the usual manner. It will be noticed that the disc F may be moved into or out of the fan-wheel while the latter is rotating at any speed and that therefore the resistance offered to the dynamometer may be varied without necessitating the stoppage of the engine under test.

RECENT DEVELOPMENT OF THE AMERICAN LOCOMOTIVE.*

BY GEORGE R. HENDERSON.

(*Continued from page 166.*)

THERE are several types of power-reversing gears, but we believe that the type in which the movements of the engineer resemble those of the ordinary reverse lever are most desirable, particularly when engines are placed in the chain gang and are not operated with a single crew. Thus, in the reversing gear which is illustrated by Fig. 7, the engineer simply pushes a small lever to the desired position and the reversing engine automatically moves the valve motion until it has assumed a position corresponding to the hand lever, and, while this hand lever may be reversed with a very rapid movement, yet the engine itself will pull the motion back slowly but surely, regardless of the speed with which the engineer has moved the controlling lever.

While piston valves have long been used in marine engineering, the general use of them in locomotives dates back a little more than ten years. The Vauclain compound locomotive with the high and low pressure cylinders superimposed, one above the other, was operated by a single piston valve for the two cylinders, this reducing the mechanism to a much simpler form than could be accomplished by means of slide valves. Previous to this there had been very few engines of the simple type equipped with piston valves, but the success which attended the use of the piston valve with the Vauclain compound induced its extension upon locomotives operated by single expansion only.

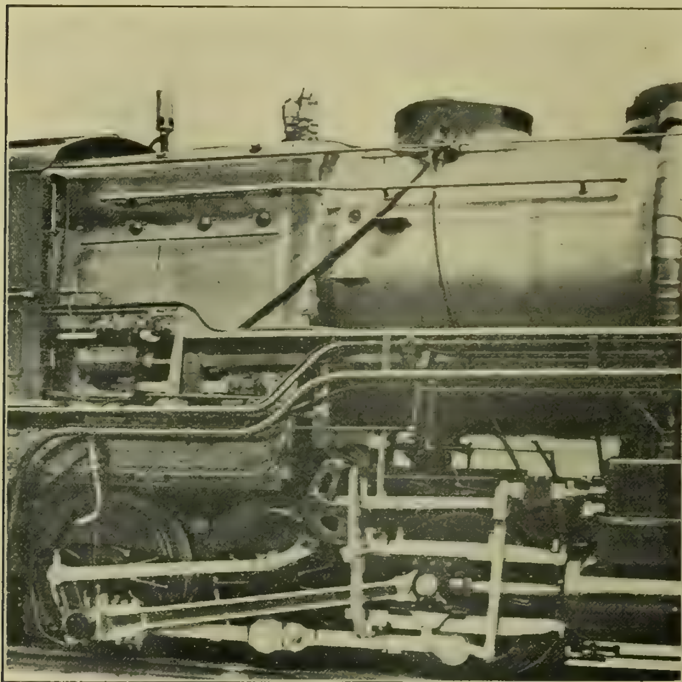


FIG. 7.—POWER REVERSE GEAR.

When the piston valve is used to replace an ordinary slide valve it is of a very simple type, and is practically a slide valve extended into a circle, with packing rings used at the several steam and exhaust edges. There has been considerable discussion as to the value of these valves as compared with slide valves, and a number of tests have been made, some showing better for one, some showing more economy for the other. There is little doubt but what this question of economy depends greatly upon the maintenance of the valve and the condition in which it is allowed to run, as a leaky valve of either type would, of course, be very wasteful of steam.

One of the principal advantages of the piston valve is the fact that it is fully balanced and easier to manipulate the engine than with a slide valve, even of the balanced type. As a matter of fact, piston valves are generally manipulated with greater ease when the throttle is open than when it is closed; still, the converse is true of balanced slide valves.

In spite of the fact that there is some doubt as to whether the piston valve is really more economical in steam consumption than the slide valve, yet they have been introduced in great numbers, partly due, no doubt, to the fact that the large cylinders require large ports, and the port opening with the piston valve can be made nearly double that possible with an ordinary slide valve. The large valves also are very little harder to handle in the cab than those of smaller diameter. Another advantage lies in the fact that piston valves can be, and generally are, so designed that the steam enters at the centre, or central admission, as it is called, and exhausts into the ends of the chamber, the valve being hollow, permitting both ends of the steam chest or valve chamber to be in communication with each other. This reduces the pressure on the valve stem packing to that of exhaust steam only, and when it is considered that the variable travel of the valve makes it much more difficult to maintain packing on the valve rod than on the piston rod, which always travels the same distance and forms no intermediate shoulders, the advantage in relieving this packing of high-pressure steam will be at once appreciated.

Reference was made above to the fact that in the Vauclain compound of the superimposed cylinder type one valve was able to regulate the admission of steam to both cylinders. In this case both the pistons worked together, being attached to the same crosshead. A later type of the balanced compound, in which the pistons move in opposite directions, has also been successfully worked by one valve, resulting in extremely simple mechanism for this type of engine.

The advantages of the Allen ported slide valve for the quicker admission of steam to the cylinders has long been appreciated, but this has not been generally introduced into piston valves, one reason, no doubt, being due to the fact that the much larger valve opening, on account of the greater length of port, made it unnecessary. With the increasing size of cylinders and the greater speeds at which it is desired to operate large tractive forces, it becomes necessary to adopt a somewhat similar arrangement for piston valves. This has been developed into the double ported piston valve, whereby there are two ports or openings, both for steam and exhaust. The advantage of this is that a higher steam line or pressure line can be maintained in the cylinder up to the point of cut-off and less back pressure during the period of exhaust, as the steam has twice the area of opening when near the points of port opening and closure than could be obtained with an ordinary valve of the same size. As this port is placed partially in the valve chamber bushing, there is little additional complication added, except in making the valve itself, but the cylinder casting can be moulded as easily in one case as in the other. While this is a very recent development, yet it promises such good results that we believe its quite general adoption is likely to be only a question of a short time.

While the boilers of locomotives have increased enormously in size, there has been little change in the actual design and construction. Of course, the larger diameters have given occasion for the introduction of thicker sheets and for joints of increased efficiency. The old double-riveted lap joint, which had an efficiency of about 70 per cent., has been superseded almost universally by the butt joint, with an efficiency of from 80 to 90 per cent. Besides reducing the thickness of the shell sheet, the butt joint pulls centrally and removes the cause of grooving, which was so often found when boilers were provided with lap joints, no matter how strongly they might be riveted. This grooving was due to the eccentric pull of the two sheets on the joints, and has been largely responsible for shell ruptures. It is, moreover, difficult to see before trouble ensues, but it reduces the section of the plate by starting a fracture at the caulking edge of the inside lap. The butt joint which has generally been introduced has a wide inside and a narrow outside cover plate, but in some cases the diamond joint has been introduced, which makes a very stiff shell at the joint. Seams have been welded, not only at the ends but sometimes for the whole width of the sheet, but, as a rule, a cover plate is put on in addition to the weld, so as not to depend entirely upon the welded joint. There are different ways of making these welds, sometimes by means of direct flame or fire, sometimes with an electric arc, and sometimes with acetylene, the latter coming now into more general use, as the apparatus is portable and does not require connection with any source of power to provide current.

* Paper presented at a meeting of the Franklin Institute, April 17th, 1912.

Cast metals have almost entirely disappeared from boiler construction, whereas in former times, with low pressures, it was considered permissible to use cast-iron dome rings and dome caps, yet these are now invariably made of pressed steel. The complete dome is sometimes pressed out of a single sheet of metal.

The firebox itself has been affected principally by the introduction of flexible staybolts. These are generally of two types, one with a spherical end encased in a cup screwed into the sheet, of which the Tate is perhaps the best illustration, and another one consists of a hinged bolt, of which the "Breakless" is the best known example. These were introduced to reduce the great number of breakages which some lines experience, particularly in the corners or ends of the firebox. Some roads even go so far as to specify that all of the firebox staybolts shall be of the flexible type, while the majority of roads are satisfied to put in only 300 or 400 of such special bolts. These bolts add about 50 cents each to the cost of a locomotive, and the question has recently been raised as to whether they are really giving the immunity from breakage which has been contended. The staybolt problem is rather a difficult question, inasmuch as if we make the bolt larger in diameter it will be stiffer and still less likely to stand transverse strain. With increasing pressures we cannot well make them thinner without reducing the spacing, and this is undesirable on account of the likelihood of the water space being choked up with mud. Then, staybolts are likely, if overheated, to let the crown sheet drop, and for this reason it is good practice to use button-headed bolts for the central rows of the crown sheet stays. The wide fireboxes have long caused the practical disappearance of crown bars, so that there are practically either radial-stayed or Belpaire type of boilers in general construction at the present time. With the Belpaire the crown sheet is naturally level, but with the radial-stayed the high portion which would be first to be uncovered by low water is often protected by button-headed bolts. Some, however, think this a disadvantage, and would prefer that a short section of the crown sheet should let go and relieve the pressure without pulling down the whole crown sheet. Records of locomotive boiler explosions, including dropped crown sheets, seem to indicate that less than 2 per cent. are due to deficient strength, and that practically all of the disasters are caused by low water, either through the negligence of the engineman or some difficulty with the water-feeding or indicating devices.

In recent years the Jacobs-Schupert firebox has been introduced as practically indestructible with even extraordinarily careless treatment in connection with fire and water. This boiler is composed of sections riveted to diaphragm sheets, so that no staybolt is used in the construction of the boiler, and some remarkable results of tests have indicated that it is very difficult, if not impossible, to cause a disaster by means of low water, even with a hot fire in the firebox. Of course, this firebox is more expensive to construct, and it is questionable whether the railroads would feel it necessary to pay this increased cost as an insurance against troubles of this kind.

The inside of the firebox is occasionally provided with arches of various types; some of these rest on tubes and some on studs, some are made of solid bricks, and some are of hollow bricks with openings through the front water leg to introduce air for combustion. Some tests recently made showed that there was little, if any, efficiency or economy afforded by means of jets of air brought in through the arch brick, and the greater expense of the brick and the difficulty of maintaining them would seem to give preference to a solid brick, particularly if there was no gain over the hollow tiles. However, these questions of combustion have been so much discussed and disputed, and as results of different tests are likely to show such a variety of results, it is doubtful whether the question of the value of the brick arch and its various forms for admitting hot air, &c., will ever be satisfactorily settled in any one way to the community at large. Most people agree that the brick arch has a very positive value in connection with smoke abatement and fuel economy; yet in some sections of the country where the flues need frequent rolling and beading it is almost impossible to maintain an arch for any length of time, and it often prevents the quick turning of a locomotive, as the man cannot get in the firebox or remove the arch until it has become sufficiently cooled. These practical considerations are often much more important in a locomotive than the mere theoretical consideration of fuel economy, as the business of moving trains is of primary importance, and anything that increases the round-house work or detains the locomotive at a terminal is bound to give way to the urgencies of transportation.

While the burning of oil instead of coal in locomotives is of quite ancient origin, having been first introduced in Russia on the Grazi-Tsaritsin Railway, it was experimentally tried in this country, but for many years had nothing to recommend it, as compared with coal, on economical grounds. The discovery of the fine deposits of oil in Texas and California, however, where coal costs $6 or $7 a ton in the latter locality, gave an impetus to this feature that was an immense benefit to the railroads in many ways. The Southern Pacific and the Santa Fé have for the last 15 years been making considerable use of crude oil in the south-west, and in later years the substitution of oil for coal has been carried to points as far east as the Rocky Mountains and generally throughout the state of Texas. The advantages, while being enormous, have been also accompanied by certain disadvantages which prevented this from being an ideal fuel.

It was found from actual tests that four barrels of oil were practically equivalent to a ton of coal of the quality of Illinois bituminous, and, as there were usually six barrels of oil required to make up a ton weight, the ratio of heating value was as 3 is to 2. This is also in proportion to the number of British thermal units developed by burning a pound of these fuels, as mine run coal gives us in the neighbourhood of 13,000 B.Th.U. and fuel oil runs about 19,000 B.Th.U.

Another incidental advantage that has been greatly appreciated in the last few years is that this oil can be put in without physical labour and makes it possible to keep steam up on a much larger engine than could be done with coal fired by hand. The unfailing source of steam is another advantage, as trains, even with the same tonnage, can make better time on heavy grades, as there is ample steam to keep the cylinders supplied at full pressure, no matter how hard the engine is being worked.

The universal method of generating steam from oil in a locomotive is by means of a special injector or atomiser, generally called a burner, in which the oil is sprayed by the steam pressure and is burned in this form of atomisation. In order to maintain the combustion, the firebox is lined part way up with firebrick, also having a floor of firebrick, which becomes quite hot and maintains the temperature high enough to ignite the oil. Formerly it was the custom to place the burner at the back end of the firebox, spraying the oil ahead underneath a brick arch somewhat similar to the ordinary brick arches used with coal, but the latest practice is to place the burner at the front of the firebox and spray the oil on a flash wall without using any arch whatever. This saves considerable expense, as the arch was very costly to maintain, sometimes falling down from the motion of the engine in two or three trips. It is also found by this location of the burner that the firebox sheets give a longer life, as the intense heat of the oil flame causes a much more rapid deterioration than with coal, and especially was this found to be the case at the seams where two thicknesses of metal were exposed to the action of the fire. With the old method of using the arch, fireboxes would often give only one-half or one-third the life of coal burners, and it was frequently necessary to renew a firebox in about one year, very largely because it was impracticable to patch the firebox on account of the double thickness of metal above-mentioned. The new method of arranging the burner has increased this life, and the practice of welding in pieces flush with the acetylene torch has also obviated the double thickness of an ordinary patch.

Even in spite of the extra cost of maintenance due to rapid firebox deterioration, the use of oil was considered very desirable, as a dollar's worth of oil would often replace three or four dollars' worth of coal. Then, there was practically no fire thrown from the stacks, which is of great benefit in a dry country, and this feature alone led to the adoption recently of fuel oil by the New York Central and the Delaware and Hudson Railroads on their lines running through the Adirondack Forest Preserve of New York State. This matter was discussed very thoroughly before the Second District Public Service Commission, which finally decided that

these roads should burn liquid fuel during the summer season in order to prevent the extensive forest losses which had resulted from fire thrown from locomotive stacks or dropped from ash pans.

The firing of oil is, of course, a speciality, as the supply of fuel to the burner must be regulated in connection with the engineer's operation of the throttle and the reverse lever. When the engine is standing, the supply of oil must be cut down to a very small quantity, such that it will just be sufficient to maintain steam, and as soon as the throttle is opened a larger supply of oil must be given, depending upon the amount of steam required by the cylinders. It is perfectly feasible to fire a locomotive with fuel oil without the emission of smoke, except that in periods of about every half hour it is necessary to work sand through the flues in order to clean out the soot that has accumulated, and, of course, this is accompanied for a moment by the emission of dense black smoke. When the engine is working properly, however, there is only a thin haze above the stack, although the least inattention on the part of the fireman will cause either the steam pressure to drop or the emission of large quantities of smoke.

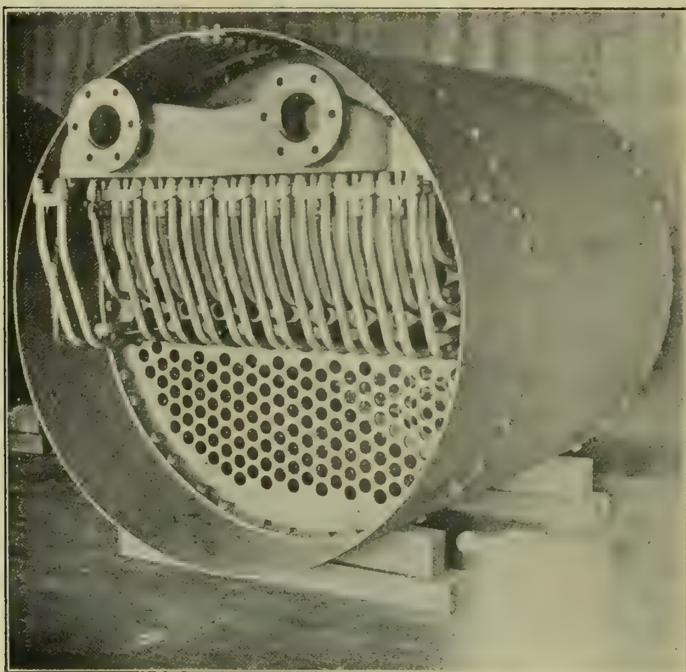


FIG. 8.—SCHMIDT SUPERHEATER.

Practically any locomotive that is suitable for burning coal can be converted into an oil burner, although there are some particular features to be borne in mind when an engine is being designed primarily for the use of liquid fuel. It is a very simple matter to construct an oil tank which shall fit into the coal space of the tender, and this is connected with hose or flexible pipes to the engine, passing through a heater so that the oil may be rendered still more fluid, if necessary. Steam jets can be used to warm the oil in the tank when necessary, and there is generally a safety connection which, in case of the separation of the engine and tender, closes the oil valve, preventing it from running over the track. The California oils are ordinarily non-inflammable at the usual temperatures, and there is little or no danger attending their use. Some of the Texas oils, however, are more readily inflammable, and it is necessary to exercise extreme caution going about a tank with an open light. Asphyxiation is also liable to occur when men go inside of tanks to clean them out, particularly with the Texas oils, and these tanks should always be steamed out thoroughly before anyone enters to do any work. The actual cost of converting a coal-burning locomotive into an oil-burner varies from $500 to $800, dependent upon the size of the engine; but, of course, the incidental expenses, such as the maintenance of storage and delivery tanks, tank cars for transporting the oil and pumping it into the storage stations, are all part of the general cost of introducing such a system, and will oftentimes amount to a great deal more than the actual equipment of the locomotives.

The large locomotive, with its heavy draught of steam upon the boiler, necessitating the combustion of great quantities of coal, has brought about a number of appliances for diminishing the work of the fireman so that he can confine his efforts to actually delivering the coal into the firebox; everything that could save a step or an extra motion of his hands or his back having in some cases been introduced, so that he could give the maximum output for the generation of steam. The old-fashioned fire door, which was swung with a chain and which was supposed to be opened and closed with each shovelful of coal, has been found troublesome in large engines, and, therefore, pneumatic fire doors have been introduced. These are arranged so that when the fireman has a shovelful of coal ready to throw into the door a pressure of the foot upon a treadle in the floor of the cab admits air to a small cylinder which slides each half of the fire door in opposite directions, thus opening the door for the admission of coal without any further action upon his part. As soon as the foot is removed from the treadle the door closes. This, besides relieving the fireman of the extra motion and effort, ensures more perfect combustion, as the door is naturally closed after each shovelful of coal. Wide fireboxes are in some cases provided with two fire doors, and it is not always as convenient for the fireman to use one door as the other, especially in connection with operating the fire door by hand, but these pneumatic devices prevent much of this trouble and assist very materially in the operation of firing.

The same principle has been applied to shaking the grates. While with short fireboxes this was a comparatively easy operation, with the present length of furnace, which is in the neighbourhood of 8ft. and 10ft., and the width, which in some cases is 8ft. or 9ft., it is not only necessary to shake the grates in sections, but it becomes quite difficult actually to do this work. Pneumatic or steam grate shakers have therefore been introduced in which a small lever operates the valve of a cylinder, which in turn gives the necessary travel to the grate arms in order to thoroughly shake up the coal bed to free it of clinkers and ashes.

Still another device has been introduced on the tenders in order to prevent the many steps needed when the coal has been partially exhausted and the fireman must go to the back of the tender coal space to shovel up the fuel. This mechanism consists principally of a steam cylinder placed inside the tank in which a piston is operated connecting to a false or inside bottom of the coal space, and when pressure is admitted to the cylinder the piston pushes up the back end of this false bottom, which is hinged to the front, allowing the coal to slide forward so it will be close to the gate and not require the extra steps and movement necessary in the ordinary type of tender.

While these different items seem small in themselves, yet, when they are all introduced together on the same engine, it is remarkable how much they save the fireman from a labour that can be performed mechanically as well as manually, and I have been impressed with this upon large locomotives where firemen have been enabled to put in very much greater amounts of coal than would ordinarily be expected.

The greatest improvement, however, has been in the development of the automatic stoker, which not only combines the several features above mentioned, but actually brings the coal from the tender and puts it in the firebox. The first type developed was probably that invented by Mr. Kincaid, a former engineer on the Chesapeake and Ohio Railway. This was really a steam shovel and placed back of the fire door, coal being thrown in the hopper from the tender by the fireman with a shovel, the apparatus, however, delivering the coal into the firebox. This represented very largely the ordinary method of firing, as the fuel was thrown on top of the fire in the furnace and regulated the supply to be put in in large or small quantities and at regular intervals, so that the smoke production could be better controlled. There were means for distributing the coal to different portions of the box, and I have seen engines come in from a run with as level a fire as could be desired, the firing having been done entirely with this device.

There was, however, no arrangement to take the coal from the tender to the stoker, and we think this is very important. Quite a number of stokers have recently been developed, in some of which coal is thrown in, as in the Kincaid by a steam

piston, the valve of which is moved by a small engine, the speed of which can be regulated, and in others the fuel is blown in by steam jets. There are also methods of introducing the coal below the grate, such as the Crawford and the Barnum stokers. In the first of these the coal is pushed forward under the grate by means of pistons through tubes and slowly pushes up and flows up over the grate. In the latter stoker this is done by the operation of worms similar to those used in flour mills. The coal in both cases is carried from the tender by means of worms or a conveyer. As the rate of combustion in a modern locomotive can be forced up to 200lbs. of coal per square foot of grate surface per hour, it is evident that the problem is not only to get sufficient coal into the firebox, but also to get it in such condition that it will be ignited and burn at the desired rate. Naturally an under-feed device must be slower of ignition, but this takes care of itself, as the raw coal piles up over the slots and rolls over in the bright portions of the fire where the flame can reach to every surface of the piece and readily ignite it.

Claims for smoke reduction and fuel economy have been made, but really the principal point of the stoker is that it enables us to obtain more work out of the engine than would be possible with a human fireman. While the locomotive has increased in size and weight, its output in horse-power is generally very much below the increase in size, and, as previously stated, a very large engine will often develop no more actual horse-power than a much smaller one, although its tractive force will be very much greater. The limit seems to be the capabilities of the fireman, and, if this can be increased by mechanical means, not only will we be able to get more power from our engines, but the fireman's work, being less laborious, will be more attractive, so that higher-grade men can be obtained who will be able to use their heads and not depend entirely upon muscle and brawn for generation of steam.

Mention has been made above of the introduction of various superheaters and reheaters for use in connection with locomotive boilers in order to increase the output of the boiler and, incidentally, the fireman. The superheater has developed on three or four different lines, viz., one, in which a number of steam pipes are placed inside of the fire or smoke tubes, allowing the steam to be further heated by direct contact with the gases of combustion after it has passed from the boiler; another one, in which there has been a combustion chamber or pocket formed in the boiler itself, into which a receptacle has either been built or subsequently placed, permitting the steam to come in direct contact with the flue gases; and, third, in which a series of pipes are placed in the smokebox of the engine to make use of the gases after having been discharged from the flues, the steam from the boiler passing through these pipes on its way to the cylinder. It is manifestly obvious that this latter method, using only the heat remaining in the gases after having been passed through the flues, will not receive as high a temperature as that which extends through the fire tubes toward the firebox, but, at the same time, there are other advantages, several of which are that the heating surface of the boiler is not necessarily diminished by introducing this type of superheater, and that it can be applied to an existing locomotive, in many cases, without any material changes in the boiler. While the superheat obtained from the smokebox type will average only from 30° to 50° Fah., yet the fact that the moisture in the steam is thoroughly dried out and that cylinder condensation is largely reduced, has made a very good economical showing for this type of superheater. Fig. 8 shows the Schmidt fire tube and Fig. 9 the Vauclain smokebox superheater.

With the fire tube and chamber type of superheaters it is possible to get as much as 150° to 200° superheat, and some recent tests have been reported in which the temperature ran considerably higher than these figures. These superheaters, being exposed to the more or less direct action of the fire, are more liable to burn out than those in the smokebox, and are, also, as a rule, more expensive to apply and maintain.

There are many varieties of fire tube superheaters, and some of them are easy of access for removal of the superheating pipes and some are difficult. The tendency in recent designs, however, has been to develop a superheater in which the elements can readily be removed without necessitating the removal of many other parts, thereby delaying the engine in the round-house and keeping it out of service. This is an important factor in railroad operation, as no matter how much economy can be obtained from any device, if it were to cause much loss of time from actual service by requiring repeated and extensive repairs, it would not receive favourable consideration.

The action of superheat upon the work of a locomotive gives, as is well known, this advantage by increasing the volume of the steam delivered to the cylinders and, at the same time, the superheating prevents in a great measure cylinder condensation, as temperature of the steam must be lowered by the amount at least of its superheat by the processes of expansion before it can be condensed in the cylinders. The economy of superheat locomotives in coal consumption varies from 10 to 20 per cent., and cases have been recorded where as high as 30 per cent. economy has been obtained. We think, however, that under ordinary service from 15 to 25 per cent. may be expected. This has an advantage in addition to the saving in fuel consumption, in that it also saves the labours of the fireman and enables him to give a greater output in horse-power for the same amount of physical energy expended.

It has been claimed that the increased volume due to the superheating could be utilised by operating at lower boiler pressures and thus reducing the amount of repairs on boilers of locomotives, which has become very onerous under conditions existing in modern locomotive practice; so that, even if there were no especial fuel advantage obtained, there would be a saving in boiler repairs. It must be borne in mind, how-

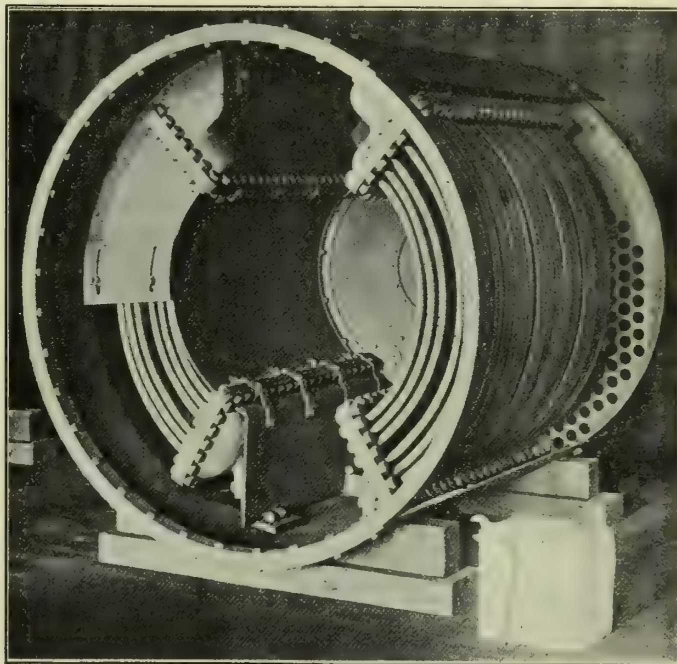


Fig. 9.—Vauclain Superheater.

ever, that the loss in pressure in passing through superheaters is sometimes quite considerable, amounting to possibly 20lbs., 30lbs., or even 40lbs. per square inch drop from the boiler to the cylinders, and in order to make up for this and to maintain the proper working pressure in the cylinders it is necessary to operate the boiler at a considerably higher pressure than it is desired to supply to the cylinders. In Germany it is quite a common practice to have two gauges, one indicating the pressure in the cylinders and the other in the boiler, and the latter is carried so as to maintain the desired pressure in the cylinders. In this country 170lbs. is a rather favoured pressure for superheater engines, and, of course, the cylinders are proportioned to give the proper tractive force with this pressure, thereby making the reciprocating parts larger than would be the case with high-pressure steam. Boilers are generally, however, designed capable of carrying 200lbs. per square inch, so that at any time the safety valves can be adjusted to allow for the drop in pressure passing through the superheater. Of course, it means a certain amount of lost work, and in some cases superheaters have been arranged in which the steam passes through a single loop in the fire tube instead of the double loop, as ordinarily used. This would naturally reduce the loss about 75 per cent., and this means a great advantage in the operation of the engine.

The action of the fire on these inside tubes when steam is not passing is sometimes prevented from overheating them by means of an automatic damper in the smokebox, which closes when no steam is passing through the superheater, thereby preventing the overheating of these pipes.

With superheaters of the chamber type it has been found that the large volume of steam outside of the throttle at times prevents a prompt response of the locomotive to the engineer's movement of the throttle lever; in starting, for instance, this chamber must fill up with steam before the pressure will accumulate in the cylinders sufficiently to move the train, and upon closing the throttle the expansion of this steam causes the engine to run farther than would otherwise be the case. It has been suggested that the throttle valve be placed outside of the superheater in order to overcome this difficulty, but this, of course, has been open to the objection that when standing the superheater might fill up with water, endangering the cylinders when the engine is started.

The whole superheater question is, in a measure, in its infancy, and, while there are a great number in use, yet we do not feel that there has been a sufficient amount of experience with them in this country so that all the benefits and difficulties can be as yet definitely determined. Anything that will increase the output of a locomotive will be looked upon with favour, unless, as stated above, there may be delays owing to necessary repairs that may more than make up for the efficiency of the engine when in operation. Of course, it must always be remembered that such devices have their benefit only when the engine is actually working steam, as on an up grade, or working on a level. During times of running down hill, standing at stations or terminals, remaining on side tracks or in the round-house, these advantages are absolutely unavailable.

From a number of tests made at the Purdue University by Prof. Goss, in which the running of the engine was intermittent, they found that the steam consumption per unit of work delivered was increased, due, no doubt, to the cooling of the cylinders and the connected parts, and that this loss increased with higher steam pressures. When the programme of operations was intermittent with equal periods of running, the loss was found to be from 5 to 10 per cent. more than that under constant running, and when the reduction by stack losses and periods of idleness were also considered, the results were about 20 per cent. less favourable than during constant operation. This, however, does not consider the absolute uselessness of this or any other device when the engine is running down hill or standing, and the additional expense for its original application to a locomotive means a constant interest charge. These things should all be considered in making any final estimates as to the value of this or any other economical device, but they are too often overlooked in the enthusiasm of those who are anxious to make a saving in coal consumption.

Reheaters have much the same function as superheaters, except that this term is applied to such devices as impart heat to the steam in its passage from the high-pressure to the low-pressure cylinders. The low-pressure cylinder, naturally, is that which produces the greatest amount of condensation, and, if we are able to reheat the steam after it has exhausted from the high-pressure cylinder, we will save considerable condensation in the low-pressure cylinder. Reheaters are seldom used alone, but are generally used in connection with superheaters which heat the steam before passing into the high-pressure cylinder. The exact amount of saving to be accomplished by a reheater is not definitely known, but it is probably somewhere in the neighbourhood of 5 to 10 per cent.

Reheaters are generally either of the box type or of the smokebox type, and in design they resemble an ordinary superheater of these two varieties.

Feed-water heaters are of a similar nature and construction, although they are generally made of the box type. The flexible boiler makes a very convenient use of the front section by placing therein a reheater, and even in some cases with rigid boilers where the length would be too great for the application of tubes satisfactorily a feed-water heater is placed in the front end and the water from the injectors flows through this feed-water heater, which is warmed by the gases of combustion after passing through the flues.

It has been customary, in many cases, to run with this section full of water, the water then passing from the top to the boiler, being fed in near the bottom of the feed-water heater. The electrolytic action, however, in many cases causes trouble and pitting of the flues and sheets, although the boiler itself is not affected in a similar way. This seems to be worse in good water districts than where scaly water is used, and it is thought to be due to the oxygen carried in with the water. The latest practice has been to connect this with the steam space directly and run it at the same level as the water in the boiler, making this really an extension of the boiler, and, while it seems somewhat strange that such should be the case, the economy, which is from 5 to 10 per cent., seems to be practically the same whether this acts entirely as a heater or whether it is connected up to form an extension of the boiler.

(To be continued.)

REMOVAL OF WASTE MATERIALS BY FANS.*

BY F. R. STILL.

THE removal of waste material from machines in industrial plants by means of fans or blowers has been in general use for over 70 years. It is the most efficient and satisfactory method known; yet even now the minimum velocity or volume of air required to convey substances of varying specific volumes and densities is not known to any definite extent. Naturally little was known about the proper design and proportion of hoods, so considerable confusion existed for years as to the proper pipe sizes. But in due course of time a standard size of pipe was generally adopted for a given duty on a machine of a certain type and capacity, and these sizes have become almost universal.

The way these sizes were arrived at was very crude. In those days (and even by some at the present time) it was generally supposed that the pressure pushed the stuff along. Nobody thought it was the velocity, and even if they had thought of it, they had no known method of measuring the velocity as an anemometer would be quickly destroyed at such high velocities. The Pitot tube for measuring velocity was not generally understood, and, in fact, it is only within the last five years that it has been developed to an extent that makes it an accurate or dependable instrument of measurement.

Hence experimenters would put up a system of pipes, add the areas of the branches together to determine the size of fan inlet and then try the fan at varying speeds, try different shapes and proportions of the hoods, &c., until the system seemed to work all right. Probably the very next job would fail to work because the piping system was more extensive or the outlet from the shaving vault was too small, thus causing undue back pressure or some other of the many things which can happen around such plants. The first things always resorted to was to "speed up the fan." If it worked it was "a fine job." If, however, that did not prove effective, then the remote sections of the main pipe were taken down, the larger pipe moved along and supplanted by still larger pipe near the fan, a larger fan installed and larger branches to those machines which did not seem to have enough "draw" to them. After several similar experiences by the different builders of such equipment, they all gradually arrived at one standard size of branch pipe for a certain duty, and these sizes have been quite closely adhered to down to the present time.

About the time the general form of hoods and pipe sizes had been standardised, considerable stir was created by inventors of "dust arresters" or "dust separators" or "dust collectors," as they are variously known by different makers. These were used to trade on for many years, most extravagant claims being made for some of them, and the prospective purchaser was often in a perfect maze of claims, guarantees, contradictions, and threats. This, by-the-way, has not entirely subsided yet, though less attention is paid to it now.

Later a new angle to the business was introduced by means of the euphonious words, "low-speed and low-power fans." The methods pursued in the introduction of this device were almost identical with those used to push the various makes of dust separators years before, and it is safe to prophesy about the same finish eventually. Suffice it to say here that nothing can be accomplished by such fans that cannot be accomplished

* From a paper read before the American Society of Heating and Ventilating Engineers, Detroit, Mich., July 12th.

by any standard type of exhaust fan with even less power when properly applied than the former requires. This name has proved a good thing to trade on and is now being pushed to the limit, but the people will eventually learn there is nothing in it.

Investigations and experiments should first determine what velocity is required to move different substances of varying weights and bulk. Then should be determined what proportionate volume of air is required to move in a unit of time a specific volume of different substances having varying weights and bulk. Air pressure is only a measure of velocity and resistance beyond which it has nothing to do with the moving of material, as many suppose.

The relative area of a substance has a great deal to do with the ease with which it can be moved by air. For instance, a comparatively low velocity will move a cubic foot of powdered coal which will pass through a 100-mesh wire screen. It will take double the velocity to move a cubic foot of coal which will pass through a 25-mesh screen. But a centrifugal fan cannot produce high enough velocity to move a cubic foot of coal in a solid block.

The same is true of many other substances; take, for instance, shavings and dust from planing-mill machinery. Twenty feet per second will move the lighter dust; 40ft. will move the shavings; 50ft. will move the sawdust, but there are knots, blocks, &c., which also have to be taken care of, and these sometimes require 60ft. or more per second. Hence the velocity has to be selected which will take care of the largest and heaviest pieces likely to enter the system.

From this it will readily be seen how essential it is for economical operation to know what is the lowest velocity required to move a given substance, as the frictional loss multiplies directly as the square of, and the power to drive the fan directly as the cube of the velocity. For example, if only 40ft. per second is necessary and 80ft. is provided and at the lower velocity it requires 25 h.p., it would require 200 h.p. at the higher speed. This is not an absurd comparison, as many are the plants where just such a comparative waste of power is taking place.

Frequently the velocity as predetermined may be correct, but the volume of air for the volume of material to be handled in a given unit of time may be sufficient. In other words, the ducts are too small. Hence the fan has to be speeded up to create a higher velocity in order to move the requisite volume of air. This has exactly the same effect on the power as would the velocity if it had been figured too high at first. An example of this latter character came under observation about a year ago, in one of the largest mills in the South. Six very large double-exhaust fans were installed, driven by direct-connected electric motors. The planing-mill machines are all high speed, having three or four times the surfacing speed of the older types; hence there is proportionately a greater volume of refuse to handle. The pipes attached to the hoods on the machines, being about the standard size, failed to take care of the refuse properly. The owners, having lost confidence in the contractor who installed the plant, sent in the plans with a request that they be advised as to the best course to pursue to put the plant in a condition which would be satisfactory to them.

A careful analysis of the situation showed it would require 438 h.p. additional to do the work with the existing plant by speeding it up; whereas, by revising the plant on a larger scale, proportionate to the work to be done, it would require 156 h.p. additional. Hence the saving would be 282 h.p. by changing the plant over. At the conservative figure of $40 per horse-power per annum, this would indicate a saving of $11,280, which, at 5 per cent., would represent the interest on an investment of $225,000. The owners of this plant have spent thousands of dollars experimenting on processes to utilise the waste from this mill for making various by-products, some of which have great value; hence they are more conservative about the consumption of refuse for fuel than are many others in a similar line of work.

Table I. gives the standard diameters to attach to the hoods enclosing the knives and saws of ordinary machines.

Moulders, buzz planers, pony planers, diagonal planers, jointers, and all other machines having knives or saws of dimensions given, will require pipes of their respective diameters. Timber planers require 25 per cent. larger pipes than ordinary planers. High-speed planers and matchers require about 50 per cent. more area than is indicated in the table.

TABLE I.—*Sizes of Pipes for Planing Mill Machinery.*

Upper Cylinder.		Lower Cylinder.	
Length of Knives.	Diameter of Pipe.	Length of Knives.	Diameter of Pipe
5in.	4in.	5in.	4in.
10in.	5in.	10in.	5in.
14in.	6in.	14in.	5in.
24in.	7in.	24in.	6in.
30in.	7in.	30in.	7in.

	Diameter of Pipe.
Matcher heads, each	5in.
Sash and cabinet shaper, each head	4in.
Door tenoner	5in.
Sash tenoner	4in.
Door and sash sticker, each head	4in.
Blind slat sticker	4in.
Blind rail router	4in.
Panel raiser, each head	4in.
Sand drum, 24in. long	4in.
Sand drum, 30in. long	5in.
Mortiser, floor spout	6in.
Floor sweep-up	6in.
Rip-saw and re-saws—	
10in. to 16in. diam.	4in.
18in. to 24in. diam.	5in.
42in. to 60in. diam.	6in.
Cut-off and grooving saws—	
10in. to 16in. diam.	4in.
18in. to 24in. diam.	5in.
Band saws, small	3in.

If the fan selected is a size or two larger than the sum of the areas would indicate, it will do the work when running at a very much slower speed, and will require less power. For example, supposing the plant requires a 12in. main, which with the branches and separator offers a resistance of, say, $4\frac{3}{4}$in. water gauge. If a fan having a 12in. inlet should be attached it would have to run at about 1,865 revs. per minute, requiring $5\frac{5}{8}$ h.p.; whereas, if a fan having an 18in. inlet were attached to produce the same velocity, it would only have to run at 1,040 revs. per minute, requiring $5\frac{1}{4}$ h.p. Thus the speed would be reduced 44 per cent. and the power reduced more than 10 per cent.

Hoods are never carried in stock by anybody, there being such a variety of makes and sizes of machines as to preclude the possibility of making a standard to fit one make of machine that will fit any other make. A governing principle for the design of hoods is to so shape them that the refuse from the knives or saws is shown directly to a point where it will be caught by the highest velocity of the air.

The hood over the upper knives on a surfacer has a mouth at the bottom several times the area of the pipe; consequently it has very little lifting power at the mouth. Immediately above the apron around the knives the hood is drawn in from all four sides so as to reduce the area to about equal the pipe area; it is also drawn back at a considerable angle in the direction the shavings fly from the knives. Thus the shavings fly at once into the contracted area, where the velocity is the highest, and, being once set in motion, it is easy to keep them moving.

The hood to the bottom knives is not much more than a shallow hopper with a narrow slit at the bottom leading into a horizontal pipe. The end of the pipe is usually left open to prevent clogging up, as otherwise if the shavings should bridge over the opening in the bottom of the hopper it would shut off all circulation and the pipe would then become dead until cleaned out. The hoods to the side heads are sometimes very complex in form, but the same principles are employed in their design as for the upper hoods.

Where the branch pipes attach to the main they should enter at an angle of not more than 45°, and 30° or less is better. Never attach a branch at right angles to the main. Two branches should never enter the main directly opposite each other;

also avoid the use of Y-branches, as the two currents in conflict retard the flow, sometimes causing the pipes to clog.

Elbows should have a radius in the throat twice the diameter of the pipe. For example, a 6in. pipe should have a radius of 12in. in the throat. There is no advantage in making the radius more than twice the diameter.

A right angle elbow in a 6in. pipe offers as much resistance as a straight pipe of the same diameter 44ft. long.

With a radius of half the diameter, it is equal to a straight pipe 15ft. long.

With a radius of one diameter it is equal to a straight pipe 5½ft. long.

With a radius of two diameters, it is equal to a straight pipe 2¼ft. long.

By making the radius more than twice, the resistance begins to increase again until at six diameters it is equal to a straight pipe 3ft. long. This is due to the greater distance the air is under compression on one side of the pipe while making the turn.

Friction of the air travelling through the pipes is another and very essential point for consideration, and it must be determined in order to know the minimum speed at which the fan can be run. Careful experiments have shown that a length of round pipe from 62 to 72 times its diameter will produce friction equivalent to the velocity head, the shorter length applying to small pipes, because of the relatively greater resistance the roughness of the surface presents per unit of volume. In actual practice it is customary to allow about 40 diameters, to compensate for branch tees, reducers, dents, &c. The refuse carried along by the air also increases the resistance somewhat.

Rectangular pipes can be compared with round pipes by multiplying the area of the square pipe by four and dividing by the perimeter of the square pipe ; the result is the corresponding diameter of a round pipe for the same velocity.

The friction for varying diameters of round pipes is inversely proportional to their diameters, at a given velocity.

The friction of rectangular pipes at the same velocity varies inversely as the square root of their respective areas.

The friction of any pipe is directly proportional to its length.

In the application of fans to the removal of smoke, fumes, fine dust, obnoxious gases, &c., great care has to be exercised in so designing the hoods that they will not interfere with the process, that they will not be in the way of the mechanics and still be capable of catching the floating material before it gets into the room. Most failures in such installations are due to the pipes being too small.

For example, supposing a hood of conical form is 3ft. in diameter at the mouth with a 7in. pipe attached at the top. With a velocity of 4,000ft. per minute in the 7in. pipe, the velocity is only 151ft. at the mouth, or less, about 2·5ft. per second.

A very efficient though somewhat expensive hood of this type is to put one hood inside the other, leaving about ⅜in. space between all around the bottom, and then run a nozzle from the apex of the inner cone up into the pipe which is attached to the outer cone. The nozzle should be about half the area of the pipe. With such a hood anything that rises up into it cannot escape around the rim even if it is not drawn off by the central connection.

A common rough rule for determining the diameter of pipe for round conical hoods is to make the bell mouth 1ft. larger in diameter than the apparatus it is to cover and increase this diameter 1ft. for every 2ft. elevation above 2ft. ; then to make the pipe one-sixth the final diameter of the mouth as thus determined. For instance, a kettle 2·5ft. diam., having the bottom of the hood 2ft. above it, would have a hood 3·5ft. diam. or 42in. ; the pipe would be one-sixth of this or 7in. diam.

Explosion at a German Ironworks.—An accident occurred on Tuesday morning last at the Hoesch Iron and Steel Works, Dortmund, by which a number of workmen were killed. Twenty-two men were at work on a slag heap, when, it is stated, an explosion took place in the very midst of it. Part of the heap broke up, and the unfortunate men were buried. Three or four were rescued alive, but there is no hope of saving the rest. Twelve bodies have been recovered. The remainder are still covered by masses of slag, and must have long been suffocated.

PATTERN-MAKING.*

BY T. R. SCHOFIELD.

THE present paper is an attempt to outline briefly the fundamental principles on which the work of the pattern-maker is based, as modified by the influence of modern engineering and foundry developments. "That which is, is right," is not the sentiment which has brought engineering to its present state of efficiency, and it is a sentiment of which the pattern-maker above all others needs to beware, if he thinks he has attained finality in his methods.

His very existence, almost, is bound up inseparably with the continued progress of engineering ; should finality be reached in mechanical engineering, the pattern-maker, who is the first to benefit from new designs, would be the first to suffer from the continuance on stereotyped designs.

When engineering made its first great advance, considerations of economy and expedition caused the pattern-maker to take his place as a specialist in this branch, in succession to the old-time millwright ; since then progress has been very rapid, but still, generally speaking, the same motives which made him a specialist continue to be a controlling factor in deciding on the correct form which his work shall take.

The wisdom of his decision is not in question in the case of simple elements, when the pattern is merely a facsimile of the required castings, though sometimes such patterns are rather more ornamental than useful, bearing evidence that time has been spent imparting a fine finish, which time could have been devoted to gaining a more accurate conception of the purpose for which the pattern was made.

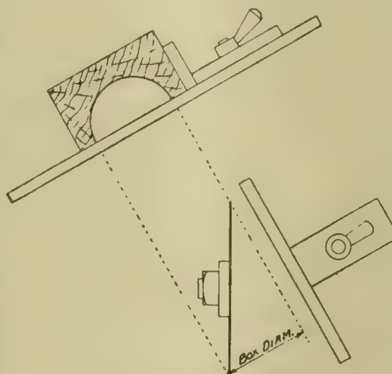


FIG. 1.

In castings of more complex form, however, the design usually admits of several methods of moulding, and the advisability of the use or avoidance of cores and drawbacks has to be settled before the pattern is begun ; then the decision arrived at assumes a considerable degree of importance to the foundry concerned. Errors of decision in these elemental matters frequently involve the foundry in expenditure of labour which might be avoided. It is of paramount importance, therefore, that the pattern-maker should possess a tolerably exact knowledge of foundry practice and foundry economy, in order that the patterns provided shall involve a minimum of labour to produce the moulds and cores. The first problem which the pattern-maker has to solve, then, is the finding of that particular way, of all the possible ways by which a casting can be made, which shall fulfil the requirements of the foundry to the best advantage.

In time past, when patterns were laboriously hand-made and the conveniences now common in up-to-date pattern shops for rapid production were almost unknown, many ingenious methods were evolved, enabling castings to be obtained from a somewhat meagre pattern preparation. Such castings were not always as true as might be ; some of the niceties of design had to be sacrificed, and allowance for machining had to be somewhat generous, to cover inaccuracies. Still, such methods and such castings suited the needs of the time. Contingencies still occur when these makeshift methods are justifiable even at the present time, as, for instance, the familiar "1 off" job in some of its forms, and the bona-fide breakdown. Knowledge of these "cheap" methods formed no small part of the pattern-maker's stock-in-trade, but they have tended to become stereotyped into standard methods.

If it is granted that real patterns are essential to bring us nearer to the ideal of foundry efficiency, in conjunction with the enormously increased facility with which a pattern can now be made for a correspondingly reduced cost, it is evident there is not now the same justification for adoption of makeshift methods as formerly, and that continued per-

* Paper read before the British Foundrymen's Association Annual Convention, Cardiff, August, 1912.

sistence in such methods constitutes a serious bar to legitimate foundry progress.

With these few remarks by way of introduction, I propose now to present the case for a more rational handling of the every-day problems of mutual concern to pattern-maker and moulder.

Modern Developments Affecting Casting Design.—The past 10 years have witnessed intensified concentration on the part of engineers, in those spheres which are peculiarly theirs, viz., the efficient utilisation of natural sources of power, and the acceleration of production. Among prime movers we now have, for very high powers, the steam turbine and internal-combustion engines for both gas, oil, and spirit, placed upon a commercial basis. Increased efficiency, higher speeds of rotation, and higher range of temperatures, also the cutting-down to a minimum of clearance spaces, have resulted in increased complexity in the castings forming the principal elements of these engines, and have brought into prominence the need for greater precision and uniformity in such castings than has ever obtained hitherto. Leaky joints and much expensive machining and fitting are obviated by combining in a single casting, whenever possible, elements which have hitherto been made separately; these combinations are characteristic of the time, and involve both the foundryman and pattern-maker in greater responsibility for their satisfactory production.

In the sphere of rapid production, the scientific study of the principles underlying the best use of metal-cutting tools, and the introduction in recent years of high-speed steel, have completely revolutionised the design of machine tools. All-gear drivers, quick-change gear boxes, and other time-saving, production-increasing features incorporated in their design, have transformed the simplest of them into more powerful, more productive, more nearly automatic machines.

Standardised methods of handling castings in quantities for machining, to reduce costs, with the need for interchangeability, have resulted in the application of jigs for all possible purposes, and only serve to emphasize the need which exists for the highest degree of precision in the castings supplied.

It would seem reasonable to deduce from the foregoing remarks that those concerned in the economical production of castings, in order to fulfil the requirements indicated, embodying great intricacy and precision, have no small part to play in the maintenance of progress. My concern is with the attitude of the pattern-maker to these developments, how, incidentally, the foundry is affected through him, and what can be done to ensure that he shall efficiently discharge his functions as a worthy member of the advanced organisation of the engineering profession.

False Economy in Pattern-making.—The work of the pattern-maker leaves him with more scope for the exercise of initiative than almost any other branch of engineering; it is under his hand that the work of the designer first finds tangible expression, and he is frequently entrusted with a large measure of discretion and enjoys opportunities for intercourse and suggestion with the designer. The live designer does not despise his suggestions; the tangible expression above mentioned often takes forms which render it almost unrecognisable to the designer, who has to take him somewhat on trust, and in whom are induced feelings of respect (I had almost said awe) because of the uncertain factors which seem to surround the evolution from drawing to casting.

Many of the qualities which characterise the designer are also found in the successful pattern-maker; both perform certain duties which are but steps towards a final achievement; the actual work of each has no place in the finished product, and for this reason both enjoy the distinction of being called "non-producers." Some enthusiasts have carried the thought further, and styled both as "necessary evils," and I have frequently heard the pattern-maker's frame linked with that of Ishmael; so that their pursuits give them ground both for mutual respect and sympathy.

From time immemorial, money spent on making patterns has been regarded in many quarters as lost beyond recall. Certainly money spent on superfluous or unnecessary work in any department is loss, but the necessity which exists for efficient patterns surely displays the inconsistency of such an attitude. The foundations of true economy must be laid, not upon such prejudice as above mentioned, but by paying the same attention to the equipment of the pattern shop and the methods of producing the patterns as has proved so successful in the productive departments.

A pattern is a tool provided for the moulder's use, but unlike most tools, it is used in a somewhat spasmodic manner. Such patterns as are used more or less continuously, *i.e.*, standard patterns, are worthy to receive every possible attention, regardless of cost, since this is relatively small. Most patterns, however, are not used so frequently, and for this reason the relative cost increases accordingly. In any case, good castings, involving minimum labour in the foundry, and with allowances so fine as to require the minimum time for machining and fitting, demand patterns made to some recognised standard of quality. When the saving in first cost of a pattern is outweighed by the cost of extra labour in the foundry, the pattern ceases to be a cheap one.

The desirable quality of a pattern, then, is measured by the facility with which the mould is produced from it. Its purpose is strictly utilitarian, and superfluous work is to be deprecated. Such a criterion might be applied to some of the ill-considered, rough, or "jerry-built" apologies with which the moulder is painfully familiar, and I think it will be agreed that there is still scope for improvement.

With a reasonable standard of efficiency adopted, the cost need not be prohibitive if proper equipment is provided and up-to-date methods adopted to produce the patterns. In analysing the various operations necessary to make a pattern, it is my intention to show in how many ways mechanical operations can be used instead of hand operations, with an enormous reduction in cost.

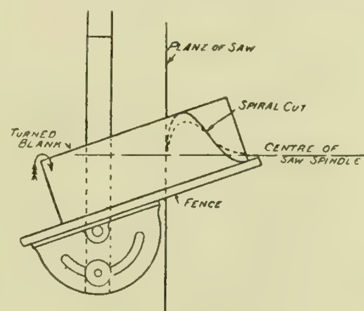


FIG. 2.

Where a broad view of economy in pattern cost is taken, so as to embrace the foundry and subsequent departments handling the work, a higher standard of finish is secured in the castings, production is enhanced, and the foundations laid for realising more fully the great potentialities of the foundry.

Pattern-making and Equipment.—The work of the pattern-maker might be roughly divided under the following: (1) Planning or previous study of methods. (2) Machine-work of sawing, planing, turning, &c. (3) Setting out and building. (4) Handwork of paring, carving, filleting, glass-papering.

As previously mentioned, the method decided on from preliminary study of the drawing has more than a passing interest to the foundry concerned, since that department ultimately suffers from errors of decision at this juncture. A thorough study of the drawing by the foreman pattern-maker enables inconsistencies in design to be corrected, and modifications to be made to simplify the work both in pattern shop and foundry. For instance, the hollow-box section, beloved of machine designers, frequently necessitates cores either suspended in the cope or insecurely balanced on chaplets in the drag, these chaplets often being cast into faces requiring to be machined, thus adding to the troubles of the machine shop. A timely suggestion being made, the designer cannot fail to appreciate the force of the argument, and small but sufficient apertures are provided, ensuring proper support in prints for the core, efficient venting, and satisfactory results. Instances could be quoted where, from a simple suggestion, the whole design has been altered, with a considerable gain in all-round efficiency.

The planning of the pattern must be, above everything, thorough, and embrace all the essentials of the construction and subsequent moulding; the foreman's decisions should be modified, as occasion arises, by consultation with the foundry head, whose advice and co-operation are of prime importance in securing the best results, and in avoiding those vexatious alterations to patterns often made necessary when found unsuitable to foundry conditions.

This preliminary work done, the job can be put in hand, accompanied by explicit instructions; the pattern-maker can proceed in the most direct manner with the work,

unhindered by doubts or fads, progressing more rapidly with it than if it were imperfectly thought out and difficulties left to be overcome as they presented themselves, which is not the modern way. It is a mere commonplace to say that economical production is secured in any branch of business by a proper planning beforehand of the work to be done, and possible difficulties as far as possible anticipated and provided for.

In work of a more or less intricate nature, involving the use of many cores, a full-size layout of the job on a board proves most helpful. Machining allowances can thus be shown; troubles in connection with the swelling of baked cores can be to some extent provided against by allowance for this being indicated on the layout, and the energy expended in rubbing cores to fit prints can be reduced if not eliminated. With the use of a layout, a large job may often be sub-divided to advantage, individuals each handling separate units which together make the complete pattern. By this means, precise methods of execution can be employed, and much economy of time effected.

Machine Work.—The machines provided for the use of pattern-makers are the same general type as usually applied to woodwork, and include machines for sawing, planing, turning, and grinding, among others. All of these are a practical necessity where a fair quantity of work is handled.

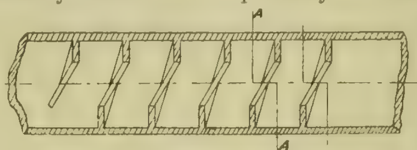


FIG. 3.

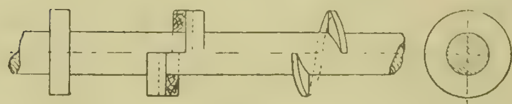


FIG. 4.

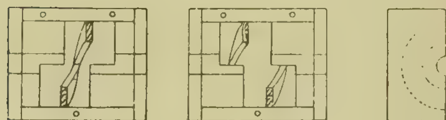


FIG. 5.

Machines specially adapted to modern shop needs are available, and only require intelligent handling to justify their installation.

The modern circular dimension saw is a precision tool; it carries two saws on separate spindles, capable of being operated alternately, by means of a handwheel movement. The height of the saw above the table is adjustable from zero to about 4in.; the fences or work guides for ripping and cross-cutting, and the work table itself, are designed to make the machine as universal in application as possible, each being capable of an angular movement of half a right angle, a few seconds only being required to set up for a job. These features enable straight work to be sawn dead to size and angle, and worked into the job without the necessity of an intermediate handling. For example, a framed core box is made in a few minutes, with the ends cut off to the correct length with allowance for draft, and checked into the sides. Polygons for hollow cylindrical patterns, and the lags for the same, require very little further attention; in fact, these machines are so valuable that one is led to think that it might be an advantage to have a small edition of them placed at the end of each bench, ready for the thousand and one jobs on which it is prepared to demonstrate its efficiency.

Two jobs of rather an unusual nature may be worth mention here, as showing the term "circular saw" to have in this connection a meaning deeper than the conventional one. The first is the roughing-out of a semi-circular half core box (see Fig. 1) or similar work. The rip or coarse-tooth saw is set so that its highest point is above the table at a distance equal to the radius; the ripping fence is then swung out of its normal position, which is parallel to the plane of saw; the angle which it makes is determined by measuring from the extreme points of the saw blade at table level perpendicular to the fence; the fence is correctly set when the difference between these measurements equals the diameter of box, or double the height of saw above the table. (The pattern-maker with mathematical tendencies might calculate the angle as follows: let D = diameter of saw, d = diameter of box; then $\frac{1}{\sqrt{D/d}-1}$ gives the sine of required angle when the actual values are substituted.) The setting accomplished, the saw is lowered, and the interior of box cut out by a series of successive cuts, the saw being raised about ¼in. each time. The final cut is not quite circular, but very little labour suffices to make it so.

The second job for the saw is the cutting of the thread on the pattern for a worm (see Fig. 2). The conventional method is to wrap a paper templet round the worm blank, on which is drawn the straight line development of the thread; then follows the relieving-out of the thread, about as tedious a job as we have to handle. By this method the pattern comes out very expensive and not very accurate.

This job can be done on the circular saw without any setting out, and with variation of pitch not exceeding one-hundredth part of an inch. The shallow-toothed cross-cut saw is set above the table an amount equal to depth of thread. The turned blank is supported against the cross-cutting fence, whose normal position is perpendicular to the plane of saw, and slides in a groove parallel to the saw; this fence is now turned through an angle equal to the angle of advance of thread (tangent of this angle equals $\frac{\text{pitch}}{\text{circumference}}$. Some adjustment has to be made, and the blank is made 3in. longer to allow of one or two trial cuts before going through.

The blank, held by the left hand against the fence, is pushed forward with the right hand until directly over the centre of saw, when the saw will have penetrated the full depth of thread; endwise movement of the blank is prevented by the saw blade. If the fence were square to the saw and the blank twisted round by the hand, a groove would be cut all round. The fence being inclined, however, the blank is rotated with the left hand, and feeds endwise, a spiral cut of the required uniform pitch resulting. Two such cuts are necessary, one for each side of the thread. Some hand labour is still required to give the taper side to thread, but it is putting it moderately to say that the total time is reduced to one-half, probably one-third, by this operation, which itself takes under half an hour.

The planing machine is so familiar as to need little comment. We rarely find means provided by which timber may be planed to parallel thickness; where jointer and thicknesser are provided, either separately or combined as one machine, handwork of this kind is almost eliminated. If due care is taken of the cutters, many jobs such as wheel rims and other circular members may be built up with good joints, without any hand planing whatever, a matter which is worth considering as one of the many economies that can be effected.

To sandpaper one's work to shape was anathema to the preceding generation of pattern-makers; we are now, without shame, grinding to shape a big percentage of our work, large and small, on the sanding disc, with results satisfactory to all concerned. The saving in cost is enormous, and its use enables many novel modes of construction to be applied, which, with the invaluable aid of leather fillets, secure the desired form and finish in a much more direct manner than is possible with hand labour. No pattern shop is complete without the sanding disc; it would be impossible to enumerate in how many ways it is advantageous, for it embraces in its scope nearly every detail of a pattern. That it is not a toy may be gathered from the fact that wheels of all sizes, up to a foot wide, are ground to shape, with correct draft, from the rough, with a speed which puts the lathe to shame. The lathe has been put partly out of commission with the advent of the sander, but has been compensated in our case by a suitably large faceplate and tilting table attachment for the lathe, thus combining in one machine the functions of both, and forming an inexpensive and efficient arrangement.

One might also mention in passing that lathes with wooden beds are not ideal for doing good work. Cases have been known where work a little too large has been accommodated by relieving a little out of the lathe bed; such a

practice pursued for long can only end in disaster. Even where iron beds are provided, one looks in vain for the slide rest, which is as invaluable for turning wood as for most other materials, where precision and time are of importance. One can only wonder, and hope for the best.

Setting Out.—It has always seemed to me, since a casting cannot be more accurate than its pattern, that the pattern deserves every care devoted to ensure that faces shall be truly perpendicular, and shaft centres bear their proper relation to each other and to the faces. To ensure this, the setting-out table of the fitting shop, with accessories in the form of angle-plate and scribing-block of adequate size, are an absolute necessity in the pattern shop. Where these facilities are provided, the work of building up the pattern, whether it be a wheel rim or a machine or engine bed, is greatly expedited; machining allowances can be cut down to minimum, and, in short, all the advantages realised of using precise, in place of rule-of-thumb methods.

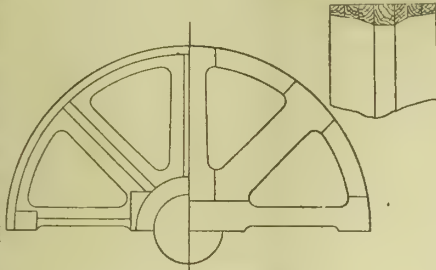


FIG. 6.

In the foregoing remarks I have tried to show that foundry efficiency demands a high standard of quality and completeness in the pattern. Also that patterns capable of meeting this demand satisfactorily, while ensuring castings on which a minimum of labour is necessary to machine and assemble, need not be prohibitive in cost, if methods are studied and equipment adapted to suit present needs.

Tube with Internal Conveyor Scroll.—The interest of the pattern-maker in his work is never more keen than when engaged on work of a somewhat unusual character, and possibly no class of work is more interesting or so puzzling to the outside observer as that in which are used assemblages of cores. The tube illustrated in Fig. 3 is of this kind; it was required to be of cast iron, ½in. thick throughout, 8½in. outside diameter, 53in. long. The clear bore was 3¾in. diam., so that the thread was 1⅞in. deep, the pitch being 3¾in. Only a few castings were wanted, and a core box the full length would have been not only expensive but a mass of loose pieces, difficult to locate in the box, without any advantage to the core-maker. The method adopted was cheap in pattern-making, and provided the foundry with a number of compact cores, quickly made and readily assembled to form the completed core.

The castings did great credit to the foundry, and were uniform, smooth, and without chaplets, a necessary feature as the tubes were subjected to great heat. The pattern was simply a plain cylindrical one, with prints at each end to carry the core. The core box contained one complete thread, and 10 cores out for the complete core. The first and tenth cores differed from the rest, which were all alike. The joint between the cores required attention, as a plain face would give feather edges and be unworkable; for that reason the face was formed with a step equal to half the pitch (see A A, Fig. 3) which overcame this difficulty, and had the additional advantage of one position only in assembling, and imparting stiffness to the finished core.

The box is shown in Fig. 5; the holes in the ends received a 1½in. print, the diameter of the barrel on which the core was built. The thread was made in four pieces; four equal segments were built on a parallel block turned to 3¾in. diam. forming a circular flange 2in. thick. This was turned to fit the box (7½in. diam.). Three of these pieces were then moved along, each ⅞in. (one-quarter the pitch) in advance; two parallel helical lines were then set out, ½in. apart, and the faces of the thread pared out by hand, these faces being square with the turned block at all points. The true form of thread was thus secured. Before removing from the block the positions of the thread sections were scribed in the box, making their ultimate location and securing an easy matter. Blocks at each end of the box gave the staggered face to the core; for the end cores these blocks were removed alternately and pieces inserted to give the required forms. The cores were, of course, made in halves and glued together, being afterwards built on a barrel, and finished off, a very satisfactory core being obtained.

A Quickly-made Half-wheel Pattern. — The advantages of modern methods are best appreciated in the case of the "hurry up" job. The wheel shown in Fig. 6 is a case in point. It was 40in. diam. and had 72 teeth 1¾in. pitch, which had to be relieved to ensure soundness; and width of the face was 12in. The teeth, though only rough approximations in form, had, of course, to be correctly spaced. The pattern had central arms, ribbed up to the rim, bosses 12in. diam. for four bolts, and bolt lugs at rim. It occupied in making 10 hours by three men.

First, a part plan and section were laid out full size on a board, and all possible information shown to expedite work; machining and draft allowances were shown, also thicknesses of timber, and, as far as practicable, other details of construction of the pattern. This preliminary work enabled the job to be efficiently sub-divided, and the work on each detail to be proceeded with directly, and completed before assembling.

No hand planing was done whatever, except circular planing of the inside of rim segments after these were band-sawn to the line and bevel. The central plate arms were first assembled, the parts being adequately secured with corrugated fasteners, which are indispensable in the pattern shop. The rim segments were then built on this, attention being devoted only to the inside, to eliminate subsequent dressing off as far as possible. When the rim was built the sander table was set to give one-tenth inch taper, and the outside of rim ground down to size, making a first-rate job. The working in of the bosses and ribs proceeded while the teeth were being spaced out and attached. The assembling of the parts completed, and very little more sufficed to hand over to the foundry an accurate, serviceable pattern. The method of previously planning the job, and proper facilities, cause a single cut at every point to suffice, instead of a roughing out, "somewhere near," with a more or less generous allowance for finally working to size. In this way much time is saved.

Trough for Large Automatic.—Most patterns are successfully handled by first constructing a stiff foundation forming part of the job; this foundation is usually either a solid block, a frame, or a box, sufficiently stiff to be relied upon while the superstructure is proceeded with. Many others are of such form and light character as to be incapable of standing alone until near completion; cases are on record where even the final coat of paint has been relied on to impart the necessary stiffness, and are somewhat analogous to the villa which is so scientifically built as to rely on every element of paint, lath, plaster, and internal paper for stability. A more desirable analogy is that of the arch, only supported until the keystone is inserted, and then capable of displaying stability for all time.

The trough illustrated in Fig. 7 was of the kind needing to be supported until practically complete; its keel was laid on the shop setting-out table, and there it remained until fit to be moved; its dimensions were roughly 6ft. by 3ft., metal ½in. thick, with 1½in. fall to the centre for drainage. The large-radius sides and corners, and the hopper form of base, made it a more difficult job than might appear. Details of construction were taken care of by previous layout and planning as far as practicable. The base was first built of four triangular frames, half-lapped together on the saw; the vertices converged at the centre, and rested on the table, the outer edges being raised on 1½in. parallel packings: this gave the right hopper form to the base. The 6in. radius mould was got out in four straight lengths, and one full circle turned for the corners, which were cut out with a fine saw, giving the four quadrants. These elements were, after finishing the inside faces, united as shown, similar to brickwork bonding; this was facilitated by all timber being machine-planed to one thickness. Rebates were cut round the base to receive the moulds and provide the necessary thick edge to the radius. Seatings for headstocks, bosses, facings, &c., are not shown, but were accurately placed with the aid of an ample scribing block working off the table face. The castings

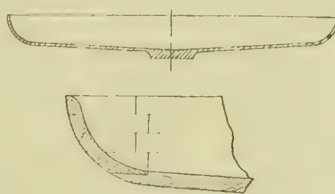


FIG. 7.

required were made without need of an iron pattern, and the pattern continues to justify the care spent on its construction, survives storage without shrinking or warping, and costs little for repairs.

It has been my aim to show that it is better to seek for economy by attention to details and methods, rather than by sacrificing the quality of the patterns to a false sense of economy. If I have been wearisome, or tended to overstate some of the trifles that seem to me to demand attention in the interests of progress, I hope I may be excused on the ground that in attention to trifles lies our hope of perfection.

INDUSTRIAL AND TRADE NOTES.

Trade Circulars.—We have received from D. Brown & Co., Huddersfield, a little pamphlet describing the principal features of their "valveless" engine as applied to a motor-car.—Adolph Bleichert and Co. send us some circulars describing their wire ropeways and other loading and transport plants, with photo views of actual installations.

Foreign Warship Orders for British Firms.—The Russian Government have placed with John Brown, Ltd., Clydebank, a contract for the turbine engines for one of several battle-ships to be built in Russian yards. It is understood that Messrs. Armstrong, Whitworth, & Co. have received confirmation of the placing of an order with them for a second Dreadnought for the Chilian Navy.

A Big Floating Dock for Canada.—The floating dock built by Messrs. Vickers, Ltd., for the Canadian Government, to be placed at Montreal, will leave for its tow across the Atlantic in a few days. This dock is 600ft. long and 135ft. wide, with sides 59ft. high, and can take on with ease any craft up to 100ft. wide. She can lift the latest types of "Dreadnought," being specially built for that purpose.

Textile Mill Electrification.—Electric power is to be adopted for the new cotton mill of Messrs. Whitehead & Sons, at Rawtenstall. Besides the generating plant the electrical equipment will include 268 loom motors for individual driving. The complete plant has been ordered from the A. E. G. Electrical Company, who will also install the necessary equipment for 300 looms, to be operated on the individual drive system, at Messrs. Nelson & Greenhalgh's mill at Whitfield.

The Care of Automatic Machines.—Serious trouble in the engineering trade is threatened because unskilled labourers are given work as minders of automatic machines, which the Amalgamated Society of Engineers contend ought to be done by skilled workers. Turners and fitters at Green Bank Foundry, Blackburn, have, for this reason struck work. The National Executive of the society have referred the question to the districts, and the trouble, it is stated, will probably extend to Durham, Yorkshire, and Warwickshire towns.

Apprentices' Strike at Glasgow.—The strike of engineer apprentices in Glasgow is spreading. Last Monday several hundred lads employed in the Dalmuir shipyard left work as a protest against deductions from wages to cover insurance payments. At Dule's locomotive works the apprentices held a meeting and decided on remaining out. They marched to Weir's pump works and persuaded the lads there to leave work again. Later in the day the apprentices from other engineering establishments joined the strikers

Boilermakers and Piecework.—Owing to the refusal of the Federation of Shipbuilding Employers to grant an advance of 4 per cent. in wages to the riveting squads, the Executive Council of the Boilermakers' Association has decided to take a ballot of its members on the questions: Are you in favour of giving one month's notice to cease work on piece-work? Are you in favour of giving one month's notice to cease work altogether to enforce a special advance of 4 per cent. on riveting rates, so that the holders-up may have 10½d. to the riveters' 1s.? The votes will be taken at the men's October meetings.

Steam Engine Makers' Society.—The August report of the Steam Engine Makers' Society states that the large majority of branches have clear books, and that there is a good demand for skilled men and vacancies all over the country. There was a marked increase in new members during the month, close upon 500 being proposed and admitted. The society, it is added, "stands pre-eminent in finance, character of membership, as continually shown by our percentage of unemployed, low percentage of superannuated members, and good standard of health by every member being medically fit on entry, and last but not least, we require a standard of ability as workmen from all candidates, as we are not out for numbers alone by any means."

The Midland Railway Carriage and Wagon Company.—The annual report shows a gross profit of £20,297. At the annual meeting the Chairman said, owing to the necessity just now for husbanding their resources, the directors thought it right, after paying debenture interest and the dividend on the debenture shares, not to pay a dividend this year on the ordinary shares, and he warned the shareholders that until it was possible to pay off a good part of the debenture loans the directors would not advise, nor would they be justified in advising, a declaration of dividends equal to those which had been paid in the past.

Railways and Cost of Insurance.—At the half-yearly meetings of railway companies, gloomy tales were told concerning the disastrous effects on receipts of the recent coal strike, and the heaviness of the burden which the charge involved by the Insurance Act will impose. The figures relating to insurance are startling, as illustrated by the following figures of annual cost to leading companies:—

London and North-Western	£64,000
Great Western	60,000
North-Eastern	40,000
Great Central	20,000
London and South-Western	20,000

Oil Fuel for Liners.—The triple-screw steamer "Niagara," which is to be launched at Clydebank to-morrow (Saturday), has been built specially for the Canadian-Australasian service which the Union Steamship Company of New Zealand are to conduct under subsidies from the Canadian and New Zealand Governments. She will be over 12,000 tons gross, and will be the largest vessel registered in Australasia. Her machinery will consist of reciprocating engines driving two shafts and a low-pressure turbine driving a centre shaft, but the innovation of special interest will be in connection with the boilers. Of these there will be ten. In six steam will be generated by coal and in four by oil fuel, while the bunkers, tanks, and boilers are all so designed that they can be adapted to carry and use oil fuel exclusively as soon as sufficient supplies can be obtained at the ports of call.

The Oil-engined Ship "Eavestone."—The departure last week of the first large British-owned motor ship, the "Eavestone," on her maiden voyage from Sunderland was followed by a successful passage to Antwerp, the journey being performed without a hitch of any kind. The four-cylinder vertical Diesel engine by which this new vessel is driven was supplied by Messrs. Richardsons, Westgarth, & Co., of Middlesbrough, under joint license from Messrs. Carels Frères, of Ghent, and the Diesel Engine Company, London. These two latter firms recently amalgamated in the formation of the Consolidation Diesel Engine Manufacturers, Ltd. The "Eavestone" left Antwerp on Thursday morning last week on her return journey to Hartlepool, and in due course will come to London, where no doubt those interested will have the opportunity of inspecting the Diesel marine engine by which the vessel is propelled.

Explosives in Coal Mines Order.—The question having been raised whether the words "magneto-electrical apparatus" as used in the Order of May 21st last include what is known as a "dynamo exploder," *i.e.*, an electrical firing apparatus consisting of an armature rotating in a permanent (non-electrical) magnetic field, as well as the form in which an armature rotates in a field formed by an electric magnet, the Home Secretary wishes it to be generally known that it was intended to include apparatus of both kinds, and he is advised that the phrase used does, in fact, include apparatus of both kinds. With regard to the requirements in Clause 2 (h) of the Order that every electrical firing apparatus shall be provided with a push button, an internal arrangement by which the firing contact is automatically made at the end of the travel of the handle, and on the release of the handle is immediately broken, performs the same function as a push button, and will be admitted as complying with the requirements in the Order as to the provision of a push button.

American Petroleum Production in 1911.—According to a report just issued by the United States Geological Survey, the petroleum production in the United States in 1911 was 220,449,391 barrels, surpassing its own record, which was made in 1910, by nearly 11,000,000 barrels. In 1910 the output was 209,557,248 barrels. The total production of the world also surpassed all previous records, amounting to over 345,000,000 barrels, and of this the United States produced more than 63 per cent. The value of this enormous output of oil in the United States for 1911 was $134,044,752, the average price being 60·8 cents a barrel. In the production for 1911 California led off, with 81,134,391 barrels; Oklahoma took second place, with 56,069,637 barrels; Illinois was third, with 31,317,038 barrels, and Louisiana was fourth, with 10,720,420 barrels. The prices of the different oils varied greatly, ranging from 47 cents to $1·32 a barrel. Thus while the produc-

tion in Pennsylvania was only 8,248,158 barrels, its value was $10,894,074, whereas Louisiana, which produced 10,720,420 barrels, received for it only $5,668,814.

Scottish Ironworkers' Wages.—Another demand for increases in wages has been made by various sections of workers in the iron foundries in Scotland. The Associated Ironmoulders of Scotland and the General Ironmoulders' Association have made a joint request for advances of ½d. per hour to workers paid by the hour, 1s. per week to moulders earning a weekly wage, and 2½ per cent. to pieceworkers. The present demand is made on account of the condition of trade which, they state, has not been in such a flourishing condition for many years. All moulders in Scotland, irrespective of district, are included in the demand, and the men's organisations ask that the increase come into operation on October 2. The Employers' Federation of the Iron and Steel Founders' Association have been given until September 4th to reply to the demand. The Gasworkers' and General Labourers' Union have also requested that an advance of 12½ per cent. be granted to all foundry workers who are members of their union, and should these increases be conceded it is probable that the employers will be compelled to make a substantial increase in their prices.

Progress of the Panama Canal.—The progress of work on the Panama Canal is dealt with in a report by the British Acting Consul at Colon. He states that ships will probably be able to pass through the canal towards the end of 1913, although the official opening has been set for January 1st, 1915. Actual working operations have progressed with a remarkable absence of serious impediments, beyond slides at Culebra Cut, which have only increased the amount of excavation to be done. The total amount excavated to the end of the eighth year was 168,486,884 cubic yards, and the amount remaining to be excavated is 26,836,495 cubic yards, of which a little more than half is to be removed by dredgers at the Atlantic and Pacific terminals. Concrete work on the locks at Gatun, Pedro Miguel, and Miraflores is almost completed, and the task of erecting gates, building emergency dams, placing the valves that will control the flow of water, and installing the machinery required for working the various parts has been begun. Studies were completed during the year for the terminal docks at both entrances to the canal; at the Atlantic entrance one new pier is being constructed, and the plans provide for four new piers as the need arises; a dry dock is being built at the Pacific entrance, and work on it, and on the quay walls surrounding it, has been commenced; a project for a series of piers extending into the anchorage basin leading into the canal is being considered. Plans for lighting the canal by beacons and buoys have been approved and the work begun.

American Motor-car Industry.—H.M. Consul-General at Chicago, in a recent report, refers to the American motor car industry, and states that unbiassed authorities now declare that, while certain makers have more orders than they can fill promptly, there are others who have large numbers of machines on hand, and on the whole there is probably a considerable excess supply. Some manufacturers have announced their 1913 models rather later than usual, owing to the large number of 1912 models which they have on hand. The cutting of prices is common, as the liberality of makers in taking old cars in part payment tends to show. The following approximate figures of the production of motor cars in the United States indicate the growth of the industry:—

Year.	Cars Built.	Total Value.	Average Value Per Car.
	No.	Dollars.	Dollars.
1904	20,100	40,200,000	2,000
1908	55,400	83,100,000	1,500
1909	82,000	98,400,000	1,200
1910	185,000	242,000,000	1,308
1911	140,000	175,000,000	1,250
1912	210,000	321,930,000	1,533

The Consul-General states that it is believed by United States motor car manufacturers that the home consumption is about as large as can be expected at present, and as conditions are favourable the manufacturers are devoting special attention to the export trade. It is accordingly probable that cars will be sold cheaper abroad than in the United States, as the idea is not so much that of profit as the avoidance of even a partial shutting down and consequent loss on the total output of the various factories.

Imperial Wireless Stations.—Copies of correspondence relating to the contract for Imperial wireless stations have just been issued in a White Paper. The tender of the Marconi Wireless Telegraph Company, submitted on February 13th, offers to erect stations capable of communicating over a range of at least 2,000 miles in England, Cyprus, Aden, South Africa, and India, and such other places as may subsequently be required. The conditions stipulate that the company shall provide complete apparatus at each station for £80,000 per station, and shall also, if required, construct buildings at cost price. The company are to work the stations for six months at cost price, and if successful working has been established at the end of that period shall hand the stations over to be worked by the Governments concerned. It is provided that the agreement embodying the undertakings and conditions shall extend for a period of 28 years from the date of the completion of the first five stations, and during its continuance the Postmaster-General shall pay to the company by way of royalty 10 per cent. of the gross receipts of all the stations erected under the provisions of the agreement. The company and Mr. Marconi will give the Postmaster-General the right to use all their inventions and patents, and the Postmaster-General will have the right to introduce any patents or inventions in wireless telegraphy in addition to or in substitution for those of the company. If at any time the Postmaster-General finds it advantageous to use a system entirely independent of the Marconi system the payment of royalty will cease. On March 5th the Postmaster-General notified his acceptance of the tender subject to certain modifications which included the possible erection of a station in Egypt instead of Cyprus. A station at Singapore was included in the agreement and another in Australia, the latter being subject to the Australian Government agreeing. The tender was finally accepted on March 7th.

American Pig Iron Production.—According to the Bulletin just issued by the American Iron and Steel Association, the total production of pig iron in the United States in the first half of 1912 was 14,072,274 tons (of 2,240lbs.), as compared with 11,982,551 tons in the second half, and 11,666,996 tons in the first half, of 1911. The production of Bessemer and low-phosphorus pig iron was 5,572,355 tons, against 4,704,879 tons in the last half of 1911, and 4,704,424 tons in the first half of 1911. The production of basic pig iron, not including charcoal of basic quality, was 5,405,376 tons, against 4,584,533 tons in the last half of 1911 and 3,935,487 tons in the first half. The production of charcoal pig iron was 166,366 tons against 117,541 tons in the last half of 1911 and 161,135 tons in the first half. The production of spiegeleisen and ferromanganese was 93,11 tons, against 107,123 tons in the last half of 1911 and 77,595 tons in the first half. The production of spiegeleisen alone was 36,145 tons, and of ferromanganese alone the production was 57,016 tons. The production of bituminous coal and coke pig iron amounted to 13,840,251 tons, as compared with 11,784,662 tons in the last half of 1911. The whole number of furnaces in blast on June 30th was 266, against 231 on December 31st, 1911, and 212 on June 30th, 1911. The number of furnaces idle, including furnaces being rebuilt June 30th, was 200, against 235 on December 31st, 1911, and 201 on June 30th, 1911. In the first six months of 1912 the number of furnaces actually in blast for a part or the whole of the time was 302, against 275 in the last half of 1911 and 297 in the first half of that year. On June 30th there were seven entirely new furnaces in course of construction, six of which will use mineral fuel and one will use charcoal. In the first six months of 1912 eight entirely new furnaces were completed, all of which are coke furnaces. Their total annual capacity amounts to 1,039,500 tons. Down to June 30th five of these furnaces had been blown in. In the first half of 1912 there were seven furnaces abandoned. These furnaces had an annual capacity of 215,000 tons.

Criticism of British Trade Methods.—Mr. C. Blakey, the Vice-Consul at Kharkov (Russia), in his annual report, criticises British trade methods in regard to export business. British manufacturers are, he considers, generally far too conservative with respect to the matter of credit, mainly no doubt because they have not studied the principles on which their Continental rivals do business. It is fighting them with one arm tied when one refuses their most powerful weapon. Provided, of course, that the giving of credit is in the hands of experienced sales' managers, and kept under proper control, such outstanding accounts are regarded on the Continent as a very excellent asset, little below fluid capital in value. Without trade the manufacturing plant becomes dead capital, whereas when business is done as above, the outstanding debts are returned within a reasonable time, and carry 5 per cent. to 6 per cent. interest. Moreover, when the manufacturer has not sufficient capital to finance the trade, Continental banks, or their London branches, are very willing to advance the money to firms of good standing for the support of this credit. Thus not only is the trade extended without extra capital, and higher prices taken than is possible with cash payment, but an additional profit is made on the difference between the interest charged to the customer and the bank rate. It is, he states, largely on this basis that German industry and German exports have, all the world over, expanded. It is by this method that German exports are still expanding. British manufacturers

and British bankers will, in his opinion, find themselves forced to adopt the German methods of giving credit for the support of the export trade. If they do not do so the British manufacturer will find himself elbowed aside when his German competitor sets seriously to work, and the British banker will see profitable banking operations monopolised by Continental banks. Where a bank is largely concerned in financing a manufacturing company it will frequently have a voice on the board of that company and influence the company's purchasing operations and trade for the benefit of other businesses in which the bank has an interest. Mr. Blakey adds that the above remarks refer more particularly to makers of machinery.

World's Output of Pig Iron.—Messrs. James Watson & Co. have compiled their annual statistics of the world's production of pig iron. They place the output for 1911 at 63,668,926 tons, a decline compared with the previous year of 1,938,862 tons, but 3,303,146 tons more than in 1909. In the United States there was a shrinkage of 3,649,201 tons on 1910, while in Great Britain there was a falling off of 498,107 tons. Germany, on the other hand, makes rapid progress, an increase of 2,617,159 tons on 1910 being shown, and on 1909 of 741,787 tons. France, Russia, and Belgium also show continued expansion, and Italy only among European countries has to be joined with Great Britain in showing a set-back. The depression of the smelting industry in West Cumberland is shown by a fall of 150,631 tons last year, while compared with 1909 the decline was 124,802 tons. Last year's decline in Cleveland was 106,689 tons, in South Wales and Monmouth 77,178 tons, in Lancashire 60,998 tons, and in Durham 52,806 tons. In Northamptonshire and Lincolnshire there were increases of 27,049 and 22,539 tons respectively. The following table shows the output of the principal iron producing countries for the past three years:—

	1909. Tons.	1910. Tons.	1911. Tons.
United States	25,795,471	27,298,545	23,649,344
Germany	12,917,653	14,793,325	15,535,112
Great Britain	9,664,287	10,216,745	9,718,638
France	3,544,638	4,032,459	4,508,022
Russia	2,817,000	2,956,000	3,521,000
Austria and Hungary	1,947,300	1,990,684	2,089,867
Belgium	1,632,350	1,803,500	2,072,843

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Elastic-fluid turbines. Harrison. 9716.
Crank and lever mechanism for transmitting power. Williams, Ward, & Smith. 14453.
Automatic turret lathes. Potter. 14600.
Centrifugal or turbo-compressors. Junkers. 14702.
Water tube boilers. Palen & Burlingham. 16765.
Cocks or valves. Thompson. 16774.
Clutch-shifting and gear-changing device. Irish. 16799.
Change-speed gearing. Mackenzie. 16936.
Apparatus for raising or forcing liquids. Siemens Bros., Kieffer, and Vernon. 17041.
Stuffing-box packing. Bennet & Sharp. 17067.
Spur gearing. Alquist. 17176.
Valves. Osborne. 17190.
Turbines. Sayer. 17338.
Rotary pumps. Pittler Universal Rotary Machine Syndicate, Ltd. 17366.
Steam-heated drying apparatus. Richard Simon & Sons, Ltd. 17671.
Turbine motor for steam or water. Turnbull. 17730.
Furnaces of steam generators. Dean. 18185.
Rotary explosion motors. Bilard & Touiller. 18241.
Variable transmission gear. Staude. 18440.
Valve-mechanism of internal combustion engines. Illston and Smith. 18828.
Screwing machines. Maiden & Maiden. 18988.
Grinding machines. Scott. 19249.
Draught regulator for boiler furnaces. Robinet. 19320.
Springs for railway vehicles. Wallace. 19476.
Internal combustion engines having rotary valves. Mead. 19878.
Manufacture of high-speed twist drills. Best. 21558.
Driving and conveyer belts. Watkinson. 21940.
Devices for relieving compression in internal combustion engines. Sangster. 22475.
Hydraulic press tools. Hele-Shaw and Martineau. 23803.
Turbines. Beshenkovsky. 23884.
Delivery valves for air compressors. Dunlop. 25715.
Propeller or centrifugal pumps. Hansen & Pedersen. 26766.
Spark arrester for locomotives. Borst. 26825.
Cooling-cylinders of internal combustion engines. Haubner. 27806.

1912.

Liquid-fuel burners. Littleton. 671.
Pneumatic conveying apparatus. Babcock & Wilcox, Ltd. 2408.
Vertical boilers. Giertsen. 3534.
Calculating machines. Marks. 4680 and 5651.
Controlling valve arrangements for direct acting fluid-pressure engines. Kirby. 5764.
Economisers or feed-water heaters and steam superheaters for Lancashire and other boilers. Green. 6136.
Oil burners. Marks. 6355.
Sawing machines. Hutchinson. 8530.
Apparatus for starting internal-combustion motors of the Diesel type. Jorgensen. 8580.
Hydraulic transmission apparatus for vehicles. Hele-Shaw and Martineau. 8601.
Change speed gear. Kirkup. 8753.
Tool for beading or turning over the ends of boiler tubes. Halstead & Rogerson. 8993.
Liquid fuel injector for internal-combustion engines. Moore & Ambrose, Shardlow, & Co. 9131.
Valve gear for 4-cycle explosion motors. Soc. Anon. des Automobiles and Cycles Peugeot. 10485.
Apparatus for removing soot from boilers. Bayer & Brown. 12026.
Steam superheaters. Marshall. 12304.
Soot cleaners for boilers. Eichelberger. 13242.
Carburetters for internal combustion engines. Gobbi. 14021.

ELECTRICAL, 1911.

Fittings for metallic conduits. Waterhouse and Simplex Conduits, Ltd. 14650.
Supports for electrical conductors. Callender's Cable and Construction Company, and Kay. 17294.
Earthing or bonding devices for electric conductors. W. T. Henley's Telegraph Works Company, and Bishop. 17347.
Dynamo-electric machines. Greenwood. 17835.
Testing electric meters. Murray. 18763.
Magneto-electric machines for ignition purposes. Brooks and Alston. 21025.
Electrical plug switches. MacAlister. 21168.
Apparatus for winding armatures. Ritter. 20997.
Electrodes for arc lamps. Ridings. 21647.
Magneto machines. Moore. 21755.
Electric insulators. Fuller & Fuller. 23334.
Supports for electrical conductors. Callenders Cable and Construction Company, and Kay. 23565 and 23566.

1912.

Magnet electric speed indicators. Schuster. 1288.
Electric cables for automatic telephone exchange selectors. Western Electric Company. 3980.
Electrically-heated ovens. Haddan. 5986.
Telephone exchange systems. McBerty. 8572.
Receiver for telegraph printing machines. Siemens Bros. & Co. 13490.

METAL QUOTATIONS.

TUESDAY, AUGUST 13TH.

Aluminium ingot	80/- per cwt.
„ wire, according to sizes, &c. from	102/- „
„ sheets „ „ „	120/- „
Antimony £28/-/- to	£28/10/- per ton.
Brass, rolled	8¼d. per lb.
„ tubes (brazed)	11½d. „
„ „ (solid drawn)	9¾d. „
„ „ wire	8⅝d. „
Copper, Standard	£78/12/- per ton.
Iron, Cleveland	60/10½ „
„ Scotch	66/10½ „
Lead, English	£19/15/- „
„ Foreign (soft)	£19/7/6 „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£8/5/- per bottle
Silver	28 5/16d. per oz.
Spelter	£26/-/- per ton.
Tin, block	£207/10/- „
Tin plates	14/7½ „
Zinc sheets (Silesian)	£29/5/- „
„ (Stettin; Vieille Montagne)	£29/7/6 „



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Compressed Oxygen in Diesel Engine Storage Reservoirs.

THE facts revealed by an enquiry into the circumstances attending a fatal explosion of a compressed air storage cylinder of a Diesel engine, which occurred at the Bray Electricity Station last month, suggest a hitherto unsuspected source of danger which should be noted by makers and users of this type of internal-combustion motor. The distinguishing feature of its operation is that air is compressed in the engine cylinder to a much greater extent than in the ordinary type of oil motor, in fact up to a pressure of about 500lbs. on the inch, and this sudden compression is accompanied with a rise of temperature to 1,000° Fah. or 1,100° Fah. that inflames the spray of oil which is injected without extraneous ignition. To inject this oil spray requires of course a still higher pressure than that in the engine cylinder, and this is supplied from a storage reservoir in which the pressure is pumped by an air compressor to 800lbs. or 900lbs. on the inch. This is a very high pressure to maintain, and some engine makers state that if from any cause the pressure is lost after an engine has been standing for some time it may be made good for starting purposes by replenishing the supply from storage cylinders of oxygen or carbonic acid, which, being largely used for other commercial purposes, can be easily obtained. As long as everything is normal there is nothing objectionable about this recommendation, but the Bray accident clearly indicates that while compressed carbonic acid may be used, it is very undesirable to use oxygen for this purpose, owing to its intensifying effect on the combustion of the oil spray in the engine cylinder or from its action on any oily matter that may by any means become deposited in the storage reservoir. The facts at Bray, as reported by the deputy electrical engineer, were that on the day of the accident "the starting air of the Diesel engine was lost and, following the instructions of the engine builders, the engineer sent for a cylinder of compressed oxygen and charged the storage reservoir from this cylinder, raising the pressure from 350lbs. to 700lbs. on the inch." The engine, it

is stated, "was started in the usual manner, but did not appear to be running properly," and before what was wrong could be discovered, quoting again from the report, "the fuel valve on the cylinder cover of the engine exploded; the flame from this burst along the blast pipe, reaching the storage reservoir, which then also exploded." Whether this was or was not the precise course of events, certain it is that the storage reservoir, which was about 7in. diam. by 3ft. to 4ft. in length, burst like a bomb, killing one man instantly and terribly injuring two others. The question is, Why did the cylinder explode in this violent fashion? The air pressure alone would be insufficient to account for it, and equally so would be the addition of pure oxygen to the atmospheric air (consisting of 4 parts nitrogen to 1 of oxygen), unless some combustible material were present. Now the only combustible material which could conceivably enter the receiver would be oil, and it is the possibility of this which needs to be recognised and guarded against. The broken pieces of the receiver were stated to be perfectly free from oil and this we can well believe for, even if it had existed, its combustion in an atmosphere of almost pure oxygen would remove all trace. As to how oil could get there we have only surmise to work upon, but past experience of receivers in connection with air compressing plant suggests as a reasonable probability that it came from the air compressors where oil would be employed as a lubricant, and would be carried over in vaporous form owing to the high pressure and temperature, and some of it, notwithstanding the existence of intercoolers, be deposited in the receiver. The danger of this is recognised in all large plants where air is highly compressed, and guarded against by careful periodic inspection and cleaning of all passages or vessels in which it may accumulate. Such oily deposit, it may also be pointed out, is liable to undergo a process of spontaneous combustion if mixed with carbonaceous or metallic dust, as has been shown by several explosions of air receivers at collieries owing to the rapid oxydising influence which can then come into play, while such action will of course be accelerated if the ordinary oxygen content of the atmosphere be increased by its admixture with pure oxygen. Whether the combustible material in the storage reservoir was ignited by a flame from the engine cylinder or was developed by its own oxidation in the reservoir is a matter on which we will not venture an opinion. The sequence of events, it seems to us, would be so rapid that it would be difficult to trace their exact order, or to say whether the burst fuel valve was a *cause* or a *consequence* of the explosion. It is certain, however, that compressed oxygen alone could not explode by simple ignition, and we think equally certain that oily matter of some kind was present to render the gas in the reservoir inflammable. As the existence of such matter is a source of danger, even under ordinary conditions of working when compressed air alone enters the reservoir, it is desirable users of Diesel engines should recognise the danger of its presence, and guard against it by avoiding excessive lubrication of the air-compressing cylinders, occasionally overhauling the connections and cleaning away any deposit. The objections to the use of compressed oxygen to make good a loss of pressure in the air reservoir, although based on the indirect action of this gas, are, nevertheless sufficiently serious to warrant its absolute prohibition for this purpose. The objections do not of course apply to carbonic acid, because this gas does not support combustion—its presence, in fact, would interfere with and might even prevent ignition in the engine cylinder in the initial strokes. In discussing this case we have refrained so far from suggesting another possibility of explosion because of its improbability in the circumstances under which the cylinder of compressed oxygen was obtained, but it appears desirable, in view of growing popularity of the Diesel engine and of the extent to which it may be worked by persons ignorant of chemistry, that makers in giving instructions about the use of extraneous sources of compressed gas for replenishing the lost air in the storage reservoirs should accompany them with a strong warning against the use of compressed hydrogen. To the ordinary man compressed gases are all very much alike for this purpose, and as cylinders of hydrogen can be purchased like cylinders of oxygen or carbonic acid he should be warned against the deadly peril of using hydrogen. The cylinders are usually distinguished by different colours, but this was only brought about by several disastrous explosions in lantern use in the early days of their introduction, and users in this direction are fully alive to the danger of mistaking one gas for another. The necessity of doing this needs to be as strongly impressed on all users of Diesel engines, or explosions such as that at Bray will some day be repeated, with possibly more disastrous results.

THE APPLICATION OF A FLYWHEEL TO A MULE COUNTERSHAFT.

BY T. M. RITCHIE.

A SERIES of tests have been made at the Municipal School of Technology, Manchester, with a view to determining the value or otherwise of mounting a flywheel on a mule countershaft, the results of which are recorded in Vol. 5 of the Journal of this Institution just published.

The mule under consideration is motor-driven—a 12in. pulley driving a 38in. on the line shaft, and a 28in. pulley driving a 15in. on the countershaft. Several mules are driven from this line shaft, and although the motor is rated at 20 h.p. direct current, 220 volts, great difficulty was experienced by sparking and overload, even when only one mule was running.

Where steam power is employed the great store of energy in the engine flywheel, line shaft pulleys, ropes, and other heavy gearing, together with modern engine governing and speed regulators, is sufficient to overcome any excessive momentary load caused by peaks in the power required when each carriage starts its outward run. In electric driving no such reserve occurs, and lighter gearing and higher speeds are the general practice, and so it was decided to investigate the effect of a small flywheel on the countershaft. The one fitted weighed 3 cwts., outside diameter 2ft., rim 4½in. broad, 3in. deep.

The mule is a short one of 196 spindles, gauge 1⅝in., spinning 34's, with full-sized headstock made by Hetherington, but owing to its size the power diagrams must be taken as an indication only of what happens, and not the actual power required by mules in practice. By means of a recording ammeter the power was taken, and also, by self-recording instruments, the speeds of the countershaft and tin roller were obtained. These were carefully marked so that the power and speeds could be compared for each respective draw. The motor speeds were observed. After a long series of tests with flywheel (Case I.) and without (Case II.), the curves given have been selected as typical.

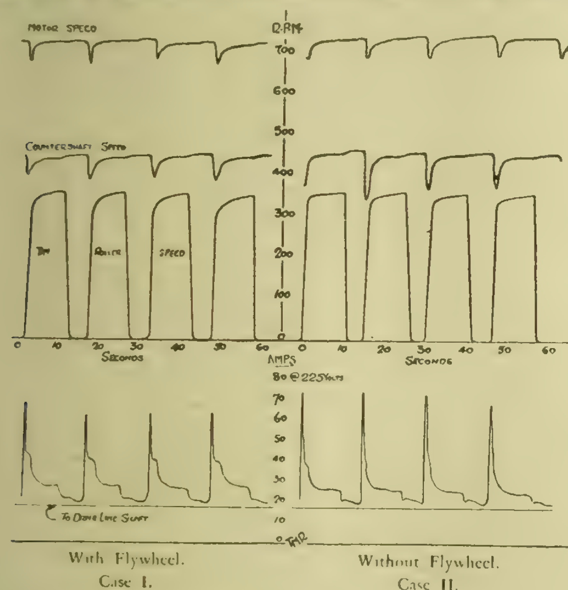
Speeds.—The motor speed varies between a maximum and a minimum, according to the fluctuation in power required, dropping suddenly when the carriage reverses. The variation in both cases is practically the same, but the motor recovers quicker in Case I., and tends to give greater regularity.

Countershaft.—The difference here is very marked, and the drop only amounts to about half where a flywheel is used, due to the energy stored assisting the motor. A large part of this difference is borne by the belt slipping on the countershaft pulley, and the smooth working of Case I. was particularly noticeable as compared with the harsh hissing noise in Case II. The diagrams clearly show the increase of speed which takes place during running in.

Tin Roller.—In Case I. the flywheel gives up its energy when the tin roller begins moving, but on this becoming exhausted, the motor is called upon to accelerate the flywheel

as well as the tin roller. Consequently the curve appears more rounded here than in Case II. This indicates that the flywheel is too light. It will be noticed, however, that the rise is more sudden, although the time taken for the tin roller to come to rest is greater. In Case I. the tin roller attained a speed of 350 revs. in two seconds, while in Case II. 2⅗ seconds were required to give the same speed. It was further observed that in the former case 61·22 seconds were required to complete four draws, as against 62 seconds in the latter case. This represents the increase in production.

Power.—The power required to drive the mule rises momentarily to a maximum when the carriage begins to move out, *i.e.*, when the tin roller begins to revolve. This falls when the parts have reached their normal speeds, and again naturally falls when the carriage and tin roller stop at the end of the draw. This fall is arrested when backing-off takes place and a slight rise is observed when the carriage starts running in, gradually falling practically to zero. The energy stored in the flywheel on the inward run is given up when the sudden grip is put on by the carriage moving out, and so the



With Flywheel.
Case I.

Without Flywheel.
Case II.

peak is reduced. When, however, the carriage speed has reached its normal, the power is normal, but since the motor must drive the flywheel in addition to the mule, this fall is not quite so low as where no flywheel is used.

Advantages.—In Case I. the mule worked with greater steadiness throughout, and especially during the earlier stages in the formation of the cops; the excessive overload was removed, which reduced wear and tear of the motor; a more uniform power consumption was obtained; the production of the mule was increased, and the fluctuation of speed in motor and countershaft was reduced.

Disadvantages.—A slight disadvantage arises from the long time taken for the parts to "come to rest" when the strap is reversed in stopping, and also in the increased difficulty of making the slight movements necessary in preparing for and during the operation of doffing. Greater practice may possibly diminish this.

Thanks are due to Mr. Winterbottom and his assistants, and also to those students of the Textile and Electrical Departments who assisted in the carrying out of the tests.

A Long Aerial Railway.—Reference is made in a recent American Consular report to an aerial railway which an English syndicate is constructing in Colombia to connect Manizales to Mariquita. The distance to be covered is approximately 40 miles, not including a branch which will run from El Zanoude to the mining district of the same name. The greatest height at which the cable will be carried is 10,600ft., in the neighbourhood of La Leonera. For every mile of cable it will be necessary to construct 15 or 16 towers. The motive power is to be derived from a point on the River Guali, where, it is said, 750 h.p. can easily be developed. It is estimated that such a railway could transport 500 tons in 24 hours, and as construction expenses are relatively light the enterprise is regarded as very promising.

THE INFLUENCE OF SULPHUR ON CAST IRON.*

BY H. I. COE, M.SC.

SULPHUR is one of the five impurities which are invariably present to a greater or less extent in all irons and steels, but unlike the other impurities its percentage is never expressed in units; in fact, more often than not the sulphur content is shown only in the second decimal place. It is seldom that sulphur in pig iron exceeds 0·3 per cent., and in such cases the iron has generally to undergo some special treatment before it can be applied to its commercial uses.

It may be of interest to consider briefly the reasons for the presence of sulphur in pig iron. The materials—ore, flux, and fuel—charged into the blast furnace contain sulphur, in the form of sulphides and sulphates, and from 5 to 10 per cent. of this sulphur enters the metal, the remainder passing into the slag. The higher the temperature of the melting zone, and the more basic the slag, the less sulphur enters the metal. The sulphur in the pig iron produced exists in combination with iron and manganese in the form of sulphide.

It is important to remember that in the remelting of iron in the cupola a considerable portion of the sulphur in the coke passes into the metal, and this fact should be borne in mind in calculating foundry mixtures. Most authorities are agreed in stating 0·03 per cent. as being the average amount by which the sulphur content is increased by remelting in the cupola, though this figure will vary according to the percentage of silicon and manganese in the iron; the higher the percentage of these elements the less sulphur will be absorbed by the iron, other conditions being similar.

The effect of sulphur on the physical and mechanical properties of cast iron has been discussed by several eminent metallurgists, the first of whom, perhaps, was Dr. Percy, who, in his book on "Iron and Steel," describes experiments performed by Karsten, which indicated that the addition of 0·5 per cent. sulphur to a melted grey iron resulted in the production of a white iron. Further experiments, performed in Dr. Percy's laboratory by R. Smith and W. Weston afforded confirmation of Karsten's results; hence, Percy states that "sulphur in certain proportions has the power of causing carbon to remain in the combined state during solidification after fusion." He refers also to the work of Caron, indicating the effect of manganese in eliminating sulphur, especially after a repeated melting, but expresses doubts as to the manner in which the manganese acts, and suggests that the elimination of the sulphur is due to oxidation by the air to sulphur dioxide, which is assisted by the manganese. Coming to more recent times, most of the information on this subject is due to J. E. Stead and to D. M. Levy, though reference should be made to the works of T. Turner, J. Keep, T. D. West, A. H. Hiorns, and others. It will be useful to discuss the work of the two first-mentioned investigators.

Dr. Stead,† in an interesting paper read before the Staffordshire Iron and Steel Institute, brings out several important points relative to sulphur and cast iron. The influence of silicon and manganese in eliminating sulphur from iron is shown, and reference is also made to Saniter's process of desulphurising iron. Some excellent sulphur prints are reproduced, which show the mode of occurrence and the segregation of sulphur in pig iron. Again, in his presidential address to the Chemistry Section of the British Association for the Advancement of Science (see "Nature," 1910, Vol. 84, p. 302), Stead has described some very interesting experiments he performed to obtain an explanation of the influences of sulphur and of silicon on cast iron. By means of analyses he shows that sulphur and silicon may exist in carbide of iron, and in connection with his experiments he makes the following statements: "It is the sulphur that crystallises with the carbide which is mainly responsible in preventing the separation of graphite by making the carbide more stable"; and "It is the instability of these silico-carbides which is mainly responsible for the graphitic character of grey irons rich in silicon and low in sulphur." Another point of interest is that the addition of one per cent. of manganese, by eliminating the sulphur from the carbide, reduces the combined carbon from

* Paper read before the British Foundrymen's Association annual convention, Cardiff, August, 1912.

† "Sulphur and Iron." Proceedings of the Staffordshire Iron and Steel Institute, 1907-08, p. 103.

3 per cent. to 0·6 per cent.; again, the micro-photographs reproduced show the separation of iron sulphide, FeS, in the carbide plates.

Levy* in his admirable Carnegie researches has thrown a flood of light on a difficult subject, and has offered an explanation of the phenomena observed, which there is every reason to respect. In passing, these researches are accompanied by exhaustive bibliographies of the subject. The chief points in the summary of his first paper are as follows: In cast iron free from silicon and manganese, sulphur up to 0·8 per cent. exists as FeS, this representing the saturation limit. The sulphide separates in the neighbourhood of 1,130° C., together with, and as a component of, the austenite-cementite eutectic, forming a triple austenite-cementite-sulphide eutectic. The balling up of the constituents of the eutectic areas at high temperatures resulting in the formation of massive cementite, which appears necessary as a preliminary to the decomposition of cementite, is prevented by the presence of iron sulphide in the eutectic as intervening layers and as sulphide films between the cementite crystals. The effect of sulphur on the strength of cast iron free from silicon and manganese is not very great, and the sulphur does little more than emphasize the hardness, brittleness, and weakness of the irons. There is no evidence to indicate chemical union with the carbon, but the research shows that the effect of silicon is a mechanical one.

In an interesting summary dealing with the constitution of cast iron, Levy † states that "sulphide of iron acts mechanically and physically in such a way as to oppose the conditions which favour the decomposition of iron carbide, from which graphite results; physically, by a lowering of melting points and by surface tension, and mechanically, by forming sulphide films and envelopes around the cementite crystals." He indicates also the probability of these emulsifying envelopes of sulphide acting in opposition to the expansion which accompanies the formation of graphite from carbide, and so retarding the change.

In later papers, dealing with the relations of manganese and sulphur in cast iron, he shows that sulphur in the presence of manganese may exist as (1) dark coloured MnS, free from FeS, and most infusible; (2) paler varieties containing up to 50 per cent. FeS in solid solution, more fusible; (3) composite sulphides consisting of MnS, FeS solid solution together with FeS itself. Manganese well in excess of the theoretical proportion was required to ensure the absence of the paler and composite forms. The latter is found to behave like iron sulphide itself in the mode and conditions of its separation from the iron, in its association with the carbide, and its influence on the carbon condition. He points out the distribution and quantity of sulphide found in specially prepared, and in commercial cast irons.

W. H. Hatfield* has recently published the analysis of the cementite in a cast iron having the following composition: Carbon, 3·16 per cent.; silicon, 0·97 per cent.; manganese, 0·04 per cent.; sulphur, 0·45 per cent.; phosphorus, 0·05 per cent. He found it to contain 0·49 per cent. silicon, traces of manganese, and no sulphur; and he remarks that the silicon content of the cementite is abnormally low, and deduces that although sulphur is not found in it, it is responsible for the comparative absence of silicon. He indicates, however, the possibility of sulphur existing to a small extent in the carbide. The author will have occasion further to refer to the work of these investigators in discussing the results of his own experiments.

The base taken in the present research was an American washed iron containing about 3·3 per cent. combined carbon, with only traces of other impurities. In the preparation of the test bars a calculated amount of low-grade ferro-silicon, made by melting a pure high-grade ferro-silicon with washed iron, was melted in a plumbago crucible with washed iron and the requisite amount of iron sulphide and a manganese alloy. It was endeavoured to keep the casting temperature as constant as possible, though no accurate determinations could be made owing to the comparatively small quantity of metal employed.

Transverse tests were made on 1in. square bars between 12in. centres, and tensile tests on round bars ¾in. diam. The majority of the bars were too hard to be machined, so that in all cases, in order to make the results strictly comparable, the tests were applied to the bars as cast; accurate measurements were made in every instance, and corrections applied to the results registered on the machines. The hardness tests were applied to the transverse bars after the skin had been filed off, and the surface polished smooth by means of emery paper. The instrument used was the scleroscope, which has been shown to give trustworthy results. Objection may be raised to merely determining the superficial hardness of the bars. The author was forced to the conclusion that in the particular irons prepared this was the only means of obtaining comparable results, since the hardness of the cross-section varied considerably from edge to edge of the bar. Again, in the case of cast iron, the superficial hardness is of considerable importance. The hardness numbers given represent, to a certain extent, the chilling action of the sand on the different irons. The results of the mechanical tests, together with the analyses of the bars, are given in Table I.

TABLE I.

No.	Transverse strength 12"×1"×1".	Deflection.	Tensile strength	Hardness number.	Total carbon.	Graphitic carbon.	Combined carbon.	Silicon.	Sulphur.	Manganese.	Phosphorus.	Remarks on the sand castings.
	Cwts.	Inches.	Tons, sq. in.		Per cent.	Per cent	Per cent	Per cent	Per cent.	Per cent.	Per cent.	
1..	25.3	0.100	10.06	58	3.04	1.77	1.27	0.80	0.010	0.025	0.01	Edges chilled, grey centre.
2..	—	—	10.46	59	3.06	0.26	2.80	0.80	0.034	0.025	0.01	White fracture, slightly mottled
3..	35.4	0.114	—	60	3.13	0.33	2.80	0.78	0.060	0.025	0.01	Ditto.
4..	39.6	0.120	10.18	58	3.00	0.33	2.67	0.82	0.103	0.025	0.01	Ditto.
5..	23.5	0.102	9.03	47	3.05	1.95	1.10	1.31	0.011	0.03	0.01	Very slight chill.
6..	32.5	0.116	13.28	50	3.16	1.45	1.61	1.35	0.050	0.03	0.01	Considerable chill.
7..	42.0	0.127	—	56	3.00	0.80	2.20	1.30	0.105	0.03	0.01	White fracture, slightly mottled
8..	35.6	0.122	—	56	2.94	0.50	2.40	1.32	0.150	0.03	0.01	Ditto.
9..	39.9	0.122	13.05	61	2.91	0.40	2.51	1.17	0.193	0.03	0.01	Only centre mottled.
10..	23.8	0.132	10.10	43	3.02	2.10	0.92	1.62	0.015	0.040	0.01	Grey fracture.
11..	24.1	0.118	15.84	48	3.12	2.12	1.00	1.60	0.031	0.040	0.01	Ditto.
12..	30.2	0.120	14.28	43	2.90	1.75	1.05	1.63	0.056	0.040	0.01	Ditto.
13..	30.7	0.126	—	40	3.02	1.80	1.22	1.40	0.084	0.040	0.01	Corners chilled.
14..	28.9	0.127	8.84	43	3.09	1.95	1.14	1.57	0.090	0.040	0.01	Ditto.
15..	26.7	0.096	14.50	49	2.94	1.69	1.25	1.52	0.103	0.040	0.01	Edges chilled.
16..	28.5	0.102	18.48	60	3.05	1.80	1.25	1.69	0.112	0.040	0.01	Ditto.
17..	30.5	0.090	12.24	60	2.87	0.67	2.20	1.55	0.155	0.040	0.01	White, mottled centre
18..	20.0	0.080	9.92	45	2.73	1.73	1.00	2.24	0.016	0.030	0.01	Grey.
19..	27.9	0.114	13.04	45	2.90	1.84	1.06	2.24	0.104	0.030	0.01	Ditto.
20..	35.7	0.150	15.30*	43	2.70	1.57	1.13	2.37	0.180	0.030	0.01	Ditto.
21..	27.3	0.097	12.61	53	2.90	1.57	1.33	1.23	0.204	0.325	0.01	Edges chilled, grey centre.
22..	29.0	0.125	14.90	44	3.06	2.34	0.72	1.05	0.027	0.857	0.01	Grey fracture.

* Specimen broke in the shoulder.

It will be observed that the table may be divided into four portions, and that consideration is taken of the effect of sulphur on cast iron containing (*a*) 0·8 per cent. silicon; (*b*) 1·3 per cent. silicon; (*c*) 1·6 per cent. silicon; and (*d*) 2·25 per cent. silicon. In addition, bars 21 and 22 were cast to show the influence of manganese on siliceous irons containing

* "Iron, Carbon, and Sulphur." C.S.M, No. II. p. 33, 1908. "A Study of the Manganese Sulphides and Silicates in Iron and Steel," C.S.M. No. III., 1911, p. 260.

† "The Constitution of Cast Irons and Carbon Steels from the Practical Standpoint." Journal Iron and Steel Institute, No. I., 1910, p. 403.

* "The Chemical Physics involved in the Precipitation of Free Carbon from the Alloys of the Iron-Carbon System." Proceedings of the Royal Society, A. Vol. 85, 1911.

sulphur. The third group is the most complete, though here, as in the other groups, the sulphur content does not exceed that met with occasionally in foundry practice.

The chemical relations of the bars present points of interest, since they afford definite knowledge of facts which, though familiar, have not been put upon a scientific basis. Briefly, the addition of sulphur causes an increase in the percentage of combined carbon, this effect being the more marked

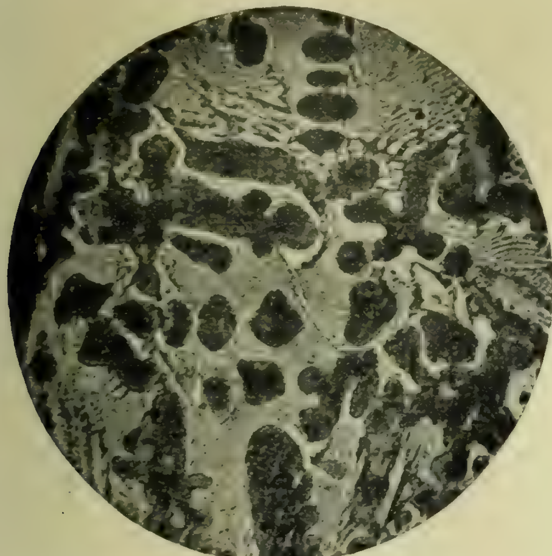


Fig. 1.
American Washed Iron. Pearlite embedded in Eutectic of Pearlite and Cementite. Magnified 125 diameters.

the lower the silicon content. In other words, a higher percentage of sulphur is required to produce a given effect on a cast iron high in silicon than on one low in silicon. A comparison of the compositions of bars 4, 9, 17, and 20 will illustrate this point. Another point of interest shown best in the group of irons containing 1·6 per cent. silicon, is the presence of a kind of critical point at near 0·1 per cent. sulphur, at which the carbon relations change somewhat suddenly.

Bar 14, containing 0·09 per cent. sulphur, is not markedly different from bar 10, with only 0·015 per cent. of sulphur as regards the relative percentage of graphitic carbon and combined carbon, but so soon as the sulphur exceeds 0·1 per cent.

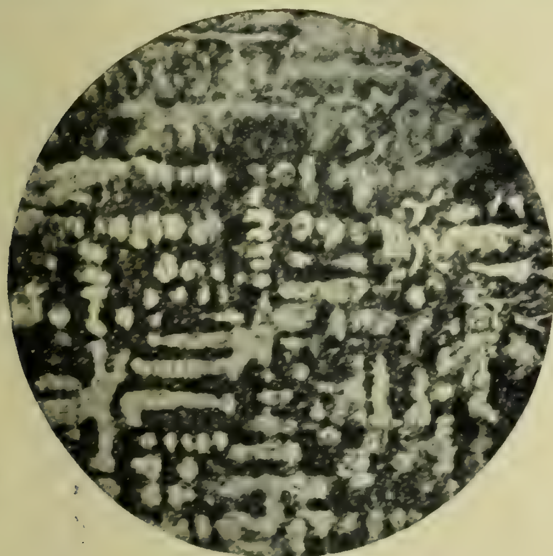


Fig. 2. (Bar 10).
Grey iron, 1·62 per cent. Silicon; 0·015 per cent. Sulphur. Pearlite (light) embedded in Eutectic of Pearlite and Graphite. A few white pools of Cementite. Magnified 125 diameters.

the percentage of combined carbon rapidly increases with a corresponding fall in the amount of graphitic carbon. The percentage of sulphur corresponding to this critical point will vary according to the percentage of silicon present. An examination of the microstructure of the bars, to which reference will be made later, affords ample confirmation of these facts. Bar 2 was poured at a low heat, and the mould of the transverse test bar was not properly fitted; the low casting temperature is responsible, the author believes, for the apparently abnormal percentage of combined carbon.

The mechanical tests are likewise interesting; both the transverse strength and the tenacity are considerably increased by the addition of sulphur. The most striking results were those obtained from bars 18, 19, and 20, containing over 2 per cent. silicon, which show that quite a considerable amount of sulphur may be added to a rich silicon iron without hardening it appreciably, and at the same time greatly increasing its strength. The author wishes to state here that during the pursuit of the present research he has met no evidence in support of the opinion generally held that sulphur increases the brittleness of cast iron; on the contrary, sulphur to the extent included in his experiments appears to increase the resistance of the metal to fracture very considerably. For instance, when pieces were required for the preparation of microscope specimens, those bars which were too hard to saw required quite severe hammering before chips were broken off. Another point worthy of notice was the comparative absence of blow-holes; only in bar 20 were a few small blow-holes observed, while near the top of bar 22 a serious "draw" was observed, containing a number of bright globular inclusions, which were thought to be globules of manganese sulphide, but which proved on analysis to be extruded portions of eutectic. Perfect eutectic structure of both the grey and the white variety was seen when these globules were examined under the microscope, Fig. 7. Shrinkage and chill were not determined

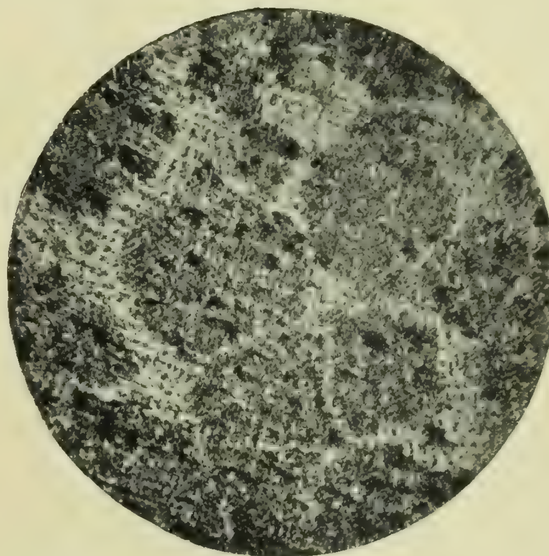


Fig. 3 (Bar 16).
1·69 per cent. Silicon; 0·11 per cent. Sulphur. Grey portions surrounded by Pearlite-Cementite Eutectic. Magnified 145 diameters.

directly, but a good indication of their probable values can be obtained by a study of the carbon conditions.

The Microstructure of the Bars.—The microstructure, in addition to bearing out the change in the condition of the carbon is shown by analysis, indicates the condition in which the sulphur exists and its distribution in the metal. The unetched specimens showed the sulphur to exist as yellow-brown blobs and lenticles of sulphide of iron, FeS. Etching in picric acid was not quite successful in throwing up the FeS in relation to the surrounding constituents, and it was found that the best method of treatment was to heat tint the polished specimen to a yellow-brown colour; the cementite assumed a pink-red tint, the pearlite showed brown, and the FeS became coloured a bright blue. Unfortunately, although for visual examination the method is excellent, the particular colours obtained did not yield satisfactory contrasts on the photographic plate.

The irons containing 1·6 per cent. silicon, and varying amounts of sulphur were examined the most carefully, since they present the most complete gradation in compositions and properties. Bar 10 (Fig. 2), which contained only a trace of sulphur, showed the typical microstructure of a pure siliceous grey iron, consisting of dendrites of pearlite embedded in a eutectic of graphite and pearlite, and containing a few pools of cementite.

The addition of sulphur up to 0·09 per cent. tends to destroy the marked dendritic structure, and yield a finer graphite; further addition of sulphur causes the retention of

rapidly increasing proportion of carbon in the combined form. Fig. 3, bar 16, at a low magnification, illustrates this tendency, and is interesting since it throws light upon the solidification sequence in such cast irons. It will be observed that grey patches (pearlite and graphite) have first solidified, and that the pearlite, iron carbide eutectic has solidified around these masses.

The FeS in the grey irons of the series was found towards the boundaries of the primary crystals, but in very few cases was it found near the flakes of graphite; in these irons the few isolated pools of cementite appeared to act as centres for the collection of a number of blobs of FeS.

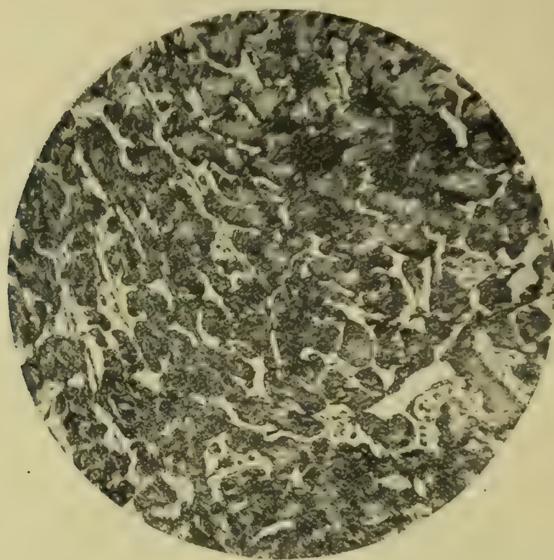


FIG. 4 (BAR 17).
1·55 per cent. Silicon; 0·15 per cent. Sulphur. Magnified 125 diameters.

In the mottled irons by far the greater portion of the FeS was observed in association with the pearlite, iron carbide eutectic, and comparatively little is seen in the grey fields. The manner in which the FeS is associated with the eutectic is interesting in view of evidence put forward by Levy. It appeared for the most part fairly intimately associated with the eutectic, and may form the third component of a triple eutectic. It was observed, however, that the degree of association appeared less in the case of those irons high in silicon than in those low in silicon.

Before attempting to explain these observations it may be well to refer once more to the fact that iron carbide has been shown to possess the property of retaining a considerable amount of silicon in solid solution, and also a small quantity of sulphur. Further, that the presence of sulphur in the iron diminishes considerably the quantity of silicon found dissolved in the iron carbide. Lastly, the effect of emulsifying films acting physically and mechanically in preventing the decomposition of iron carbide, which, it is generally acknowledged, separates out prior to the formation of graphite.

The sequence of solidification in a pure iron-carbon alloy containing about 3 per cent. carbon will easily be followed by those familiar with the iron-carbon equilibrium diagram. The fluid metal when cooled will commence to solidify in the neighbourhood of 1,290°C., and solidification will proceed progressively with fall in temperature until at 1,132° C., the remaining mother liquid solidifies at a constant temperature. The crystals which separate out first, or primary crystals, consist of a solid solution of carbon in iron (austenite), and break up at a dull-red heat (700° C.) to form pearlite. The mother liquor, which solidifies at 1,132° C., forms on solidification a eutectic consisting of alternate layers of the solid solution just mentioned, and iron carbide, or cementite, Fe_3C. Fig. 1 shows the theoretical structure of an iron containing 3 per cent. carbon.

Iron carbide decomposes fairly readily into iron and graphite according to the equation $Fe_3C = 3Fe + C$. It may be remarked that owing to the diffusion of carbon from the austenite portions into the ferrite formed, such ferrite may not be observed under the microscope.

It is now necessary to consider the effect of the addition of sulphur to such an alloy. The initial point of solidification is slightly lowered, and the sulphur (as FeS) concentrates in the mother liquor until it freezes to form the eutectic. The FeS then solidifies as a third component of the eutectic, and apparently a small quantity remains in the cementite in the state of solid solution. Owing probably both to the mechanical action suggested by Levy, and to the contained sulphur demonstrated by Stead, the cementite decomposes less readily, with the resultant tendency to the production of a white iron.

The addition of silicon instead of sulphur will result in a different mode of solidification. A portion of the silicon separates out dissolved in the austenite, while the remainder concentrates in the mother liquor until when the eutectic solidifies some is found in the austenite portion and some in the carbide portion. That dissolved in the cememtite promotes the decomposition of that constituent, hence there is a tendency to the production of a grey iron. It must be borne in mind that when either sulphur or silicon is present, much will depend on the rate of cooling during solidification.

It is now necessary to consider the case when both sulphur and silicon are present. As before, some of the silicon separates in the austenite, the remainder together with all the sulphur concentrating in the mother liquor. Now it has been shown that sulphur and silicon are antagonistic to one another, and a study of the microstructure is instructive in indicating the precise condition of affairs. It appears that if the sulphur be fairly high it tends to solidify in the very last portions of the eutectic, and most of the silicon crystallises in the first portions of the eutectic, the cementite of which, owing to its freedom from sulphur, decomposes readily.

The last portion of the eutectic to solidify contains the greater part of the sulphur, and so forms a white network around the solidified gray areas. On the other hand, when the silicon is high relatively to the sulphur, the latter as FeS appears to be expelled from the eutectic mother liquor just prior to its solidification.

When manganese is added in just sufficient quantity to combine with the sulphur present in an iron, a dove-grey crystalline sulphide is formed, which, according to Levy, consists probably of a mixture of manganese and iron sulphides. Examination of this constituent under the microscope (Fig. 6) points to its solidification in the spines of earlier formed primary crystals of austenite. When more manganese is added than is required to form MnS with the sulphur according to formula, interesting results are obtained. Bar 22 which should contain 0·2 per cent. sulphur is found to contain very much less than that amount. 0·34 per cent. manganese was lost during melting and pouring, some by oxidation, and some by the escape of manganese sulphide.

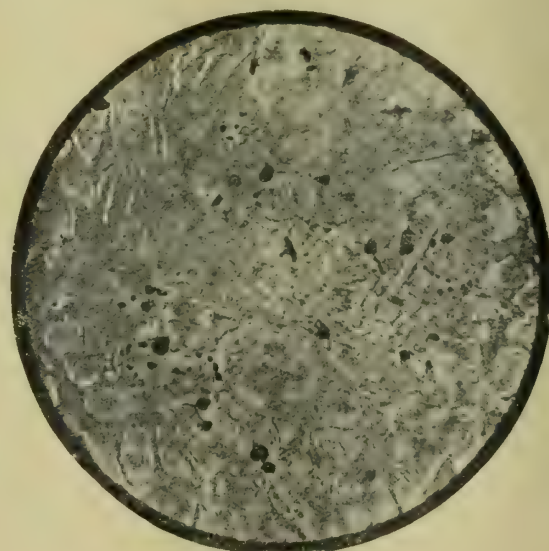


FIG. 5 (BAR 17).
Heat tinted; FeS appears black, the Pearlite light, and the Cementite in half-tone. Magnified 200 diameters.

Evidently in this melt part of the manganese combined with the sulphur to form manganese sulphide, MnS, which, owing to its high freezing point and very slight solubility

in molten cast-iron, would tend to separate out before the formation of the spines of primary crystals, and would thus rise to the top of the fluid before pouring. A small quantity of MnS is retained in the solid metal, owing probably to a slight solubility in the mother liquor after solidificaton has commenced. The effect of manganese in neutralising the powerful influence of sulphur on the condition of the carbon is well illustrated in Table I. The abnormally low combined carbon content of Bar 22 is due to the excess of manganese

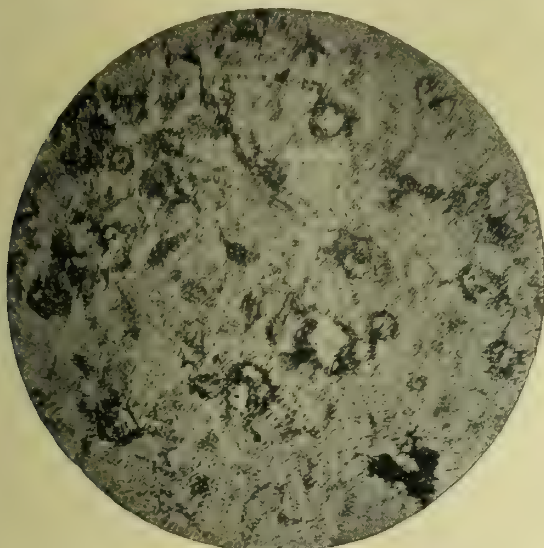


FIG 6 (BAR 21)
1·25 per cent. Silicon; 0·33 per cent. Manganese; 0·204 per cent. Sulphur. Shows cubic crystals of MnS. Magnified 350 diameters.

over that required to form MnS with the sulphur. (*Vide* paper by the author to this Association, January, 1911).

The practical application in the iron foundry of the results obtained from this research is worthy of a short discussion. It must be clearly borne in mind that these experiments were performed with the purest materials obtainable, and similar results would not be obtained with the use of commercial irons. The almost complete absence of phosphorus is a point to be mentioned; again, except in two bars, manganese is practically absent.

In spite of these facts, the author believes some useful information may be obtained from a study of Table I., the main features of which are summarised as follows:—

(*a*) The sulphur, in the absence of manganese, separates as sulphide of iron, FeS, either with, or immediately before the eutectic, according to the percentage of silicon.

(*b*) The influence of sulphur on the condition of the carbon varies according to the percentage of silicon present; when the silicon is low (about 1 per cent.), very small additions of sulphur will throw the greater part of the carbon into the combined form; when the silicon is high, the effect of sulphur is very much less marked.

(*c*) A critical point, as regards the percentage of sulphur, appears to exist, at which the effect of the sulphur changes comparatively suddenly. The position of this critical point will change according to the silicon content.

(*d*) The influence of sulphur on the mechanical properties is due chiefly to its effect on the condition of the carbon, but partly to its modifying the dendritic character of the pure siliceous irons. The transverse strength, tenacity, and hardness are increased by the addition of sulphur.

(*e*) Manganese in sufficient quantity neutralises the influence of sulphur on the condition of the carbon, and in excess it tends to the elimination of sulphur owing to the separation of MnS from the fluid cast iron before solidification commences.

The ironfounder should, therefore, carefully control the sulphur in those charges where the silicon and manganese are low, or there will be a danger of the casting being white and too hard to machine. In irons high in silicon, sulphur is far less dangerous, and for strong castings an excess of FeS is advantageous, provided it be not allowed to get so high as to make the castings too hard. The softest castings will be those containing a minimum of phosphorus consistent with the correct degree of fluidity, silicon about 2·5 per cent., manganese 0·5 per cent. in excess of that required to combine with the sulphur, and a high carbon content.

The Elimination of Sulphur from Cast Iron.—Should it be desired to use a large quantity of white scrap in the cupola charge, it may be necessary to reduce the sulphur content in order that a casting of suitable working qualities may result. This is occasionally done by the addition of ferro-manganese to the metal in the ladle. Desulphurisation would, however, be performed better by using a manganiferous pig iron as part of the charge. An interesting process, which effects a considerable reduction in the sulphur is that introduced by Saniter.* The desulphurising agent is lime, which is dissolved in calcium chloride and then brought into molecular contact with the fluid iron. The lime, owing to its great affinity for sulphur, combines with that element to form calcium sulphide, CaS, which rises to the surface of the metal. Twenty-five pounds of lime ground with the same weight of calcium chloride are sufficient considerably to reduce the sulphur in a fluid iron. The mixture should be compacted by fusion or other means at the bottom of a ladle and the molten iron poured on; the chloride melts, dissolves the lime, which then combines with the sulphur as it rises through the metal.

Calcium silicide, again, has been used successfully as a desulphurising agent.

Sulphur and Malleable Cast Iron.—The iron used for the production of the ordinary or Réaumer malleable cast iron may contain from 0·2 per cent. to 0·4 per cent. sulphur, which serves a useful purpose in yielding castings possessing a white fracture. Since the annealing is an oxidising one, the stability of the carbide as regards its decomposition into iron and graphite is of little importance.

The changes which take place in the production of blackheart castings are different from those in the Réaumer process, and depend essentially upon the decomposition of iron carbide

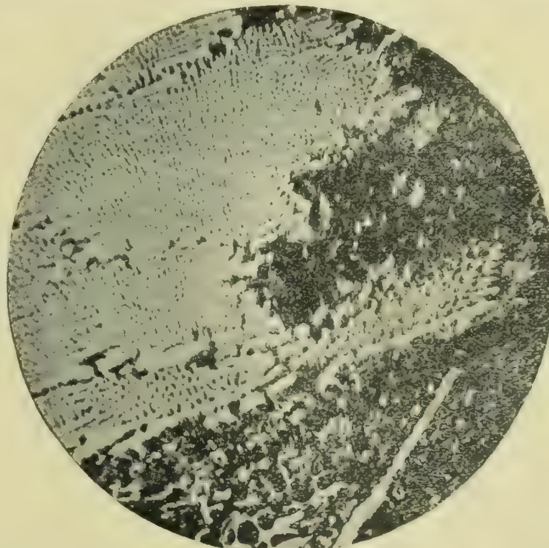


FIG. 7.
Inclusion in Blowhole in Bar 22, showing White and Grey Eu'ectic Structure. 3·93 per cent. Carbon. Magnified 250 diameters.

according to the equation $Fe_3 C = 3 Fe + C$. But sulphur acts in the direction of opposing this decomposition, and so it is found both in theory and in practice that sulphur above about 0·05 per cent. is fatal to the production of blackheart castings.

In conclusion, the author wishes to express his indebtedness to Mr. A. H. Hiorns, Head of the Department of Metallurgy in the Municipal Technical School, Birmingham, for his kindness in giving him every facility for the conduct of this research.

* "Journal Iron and Steel Institute," 1893. No. 1, p. 37.

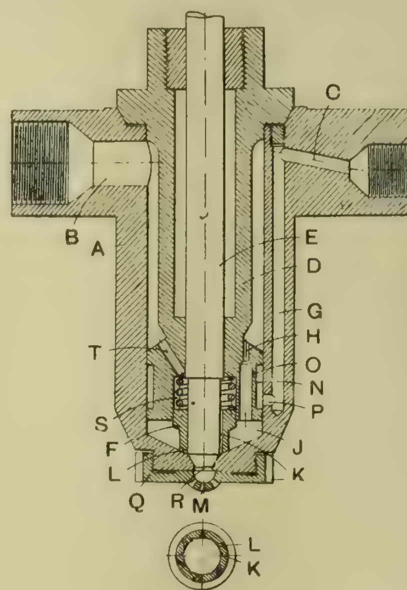
An American "Tower Bridge."— A steel bridge is nearing completion across the Willamette River at Portland, Oregon. It has two roadways, the lower for railway traffic and the upper for street cars, both with double tracks. The lift span weighs 4,300,000lbs., and, to permit the passage of vessels, the lower deck telescopes against the upper one, and, if the height is insufficient, both are raised, leaving a passage way of 140ft. above high water, 252ft. wide. Its total length is 1,623 feet, and the steel trestle approaches measure 729ft.

IRON AND STEEL INSTITUTE.

As previously announced, the autumn meeting of the Iron and Steel Institute will be held at Leeds from Monday to Friday, September 30th, and October 1st to 4th. An influential Reception Committee has been formed with Lord Airedale as chairman, the Hon. Rupert Beckett, D.L., as treasurer, and Mr. J. F. Walker (Lord Mayor's Secretary) as honorary secretary. The provisional list of papers expected to be submitted is as follows:—(1) "On Nitrogen and Iron," by J. H. Andrew (Manchester); (2) "On the Solubility of Cementite in Hardenite," by Dr. J. O. Arnold (Sheffield) and L. Aitchison (Sheffield); (3) "On the Solubility or Diffusion of Hardenite in Ferrite," by Dr. J. O. Arnold (Sheffield) and C. Chappell (Sheffield); (4) "On the Gases Evolved on Heating Steel to its Melting Point in a Vacuum," by G. Wesley Austin (Birmingham); (5) "On Allotropy in General and that of Iron in Particular," by Dr. C. Benedicks (Stockholm); (6) "On a New Type and Method of Construction of Large Gas Engines," by A. E. L. Chorlton (Manchester); (7) "On the Thermal-Magnetic Transformations of 25 per cent. Nickel Steel," by Dr. E. Colver-Glauert (Sheffield) and Dr. S. Hilpert (Charlottenburg); (8) "On a New Method for the Improvement of the Soundness of Steel Ingots by the Aid of Thermit," by Dr. Hans Goldschmidt (Essen/Ruhr); (9) "On a Method of Producing Sound Ingots," by Sir Robert A. Hadfield, F.R.S. (Sheffield); (10) "On a New Method of Revealing Segregation in Steel Ingots," by Sir Robert A. Hadfield, F.R.S. (Sheffield); (11) "On the Magnetic Properties of Manganese and Nickel Steels," by Dr S. Hilpert (Charlottenburg) and Dr. W. Mathesius (Worcester, Mass., U.S.A.); (12) "On the Question of the Existence of Commercial Hyper-Eutectic White Iron Free from Manganese," by Dr. H. M. Howe (New York); (13) "On Steel Works Yields," by P. Longmuir (Sheffield) and W. H. Robinson (Sheffield); (14), "On Some Aspects of Wire Drawing," by P. Longmuir (Sheffield); (15) "On the Manufacture of Open-hearth Steel, with reference to Improvement in Yield," by F. W. Paul (Glasgow); (16) "On Rolling-Mill Practice in the United States," by J. Puppe, D.Ing. (Breslau); (17) "On the Growth of Cast Irons after Repeated Heatings, Parts V. & VI.," by Prof. H. F. Rugan (New Orleans, U.S.A.); (18) "On the Iron Ores and Mineral Resources of Chili," by Charles Vattier (Santiago, Chili). The provisional programme of the meeting is as follows: Monday, September 30th, arrival of members at Leeds. The secretaries' office will be open at the Hall of the Philosophical and Literary Society, Park Row, from 2 p.m. until 7 p.m., for the registration of names and the issue of programmes, badges, and cards of invitation. On the Tuesday the members will be welcomed by the Lord Mayor of Leeds at the opening meeting in the Hall of the Philosophical and Literary Society. A selection of papers will subsequently be read and discussed. The afternoon will be devoted to visits to works in Leeds. In the afternoon arrangements have been made to enable the ladies taking part in the meeting to visit Bolton Abbey (by kind permission of the Duke of Devonshire, Past President of the Institute). In the evening a reception will be held by the Lord Mayor and Lady Mayoress in the City Art Gallery, Municipal Buildings, Calverley Street. During the evening a lecture on "Art in relation to the Iron Industry" will be given by Mr. Frank Rutter, B.A. (Curator of the City Art Gallery) in the Reference Library adjoining the Gallery. On the Wednesday a meeting will be held in the morning at the Hall of the Philosophical and Literary Society for the reading and discussion of papers. The afternoon will be devoted to visits to works in Leeds. Arrangements have been made to enable the ladies taking part in the meeting to visit Fountains Abbey, by kind permission of the Marquis of Ripon. In the evening a reception will be held by the University of Leeds in the University Buildings, College Road. On the Thursday the members will again meet in the morning at the Hall of the Philosophical and Literary Society for the reading and discussion of papers. In the afternoon the members and the ladies accompanying them have been invited by Lord and Lady Airedale to attend a garden party at Gledhow Hall. In the evening a special performance of the comedy, entitled "At the Barn," by Anthony P. Wharton, will be given at the Grand Theatre, by invitation of the General Reception Committee. Friday will be devoted to an excursion to North Lincolnshire and Immingham.

ATOMISER FOR OIL ENGINES.

A DESIGN of atomiser for oil engines, the invention of Sociéte des Moteurs Sabathé, of Ateliers de la Chaléassière, Saint Etienne (Loire), France, is shown in the accompanying sectional views. It comprises an outer casing A, in which is arranged a passage B for the admission of compressed air and a passage C for the supply of liquid fuel. The passage C communicates with a longitudinal passage G which is connected with the interior of the casing by an opening P. Internally the casing A constitutes a cup J presenting an opening R upon



ATOMISER FOR OIL ENGINES.

which the needle E bears; this needle is controlled by distributing mechanism and regulates the admission of fuel to the cylinder. A cap Q is screwed to the casing and is provided at its centre with radiating apertures M. The casing A contains an inner casing D which serves to guide the needle E and contains a stuffing gland. The lower part of this casing is guided and centred upon the inner wall of the casing. It presents a channel N through which the liquid fuel supplied through the opening P enters. The inner casing D has perforations H which widen out at their lower part and communicate through openings O with the channel N. The fuel to be atomised is thus subjected to a pressure equal to that of the injecting air. A housing S formed in the casing D contains an atomising sleeve F surrounding the needle E. In order to conduct the compressed air into the chamber S the casing D is provided with a number of perforations T. The sleeve F is provided with a number of slots K for the passage of the air and slots L for the passage of the liquid fuel.

The device acts in the following manner: At its lower part the casing A contains a certain quantity of fuel upon which the pressure of the injection air entering through the openings H is exerted. When the needle rises, it uncovers the slots K and L simultaneously. The fuel at once flows immediately through the slots L, while the air coming from the jet B and conducted through the apertures T into the chamber S passes through the slots K below the needle E. Owing to the convergence of the slots L, an eddying sheet of fuel is formed in the opening R and the air projected through the slot K divides the sheet and atomises it. The jet of atomised fuel escapes through the openings M.

THIRTY YEARS' PROGRESS IN THE ELECTRIC FURNACE.*

BY F. A. J. FITZGERALD.

There has been so much written about the electric furnace since it entered into regular commercial use about 20 years ago, that a presentation of a paper on the subject treating it in a general way is not apt to be interesting. It is now 30 years since Sir William Siemens melted about 20lbs. of steel, as well as platinum in notable quantities, in an electric furnace with which he had been experimenting since 1878, and since then the electric furnace has so far developed that there are great numbers, both in Europe and America, regularly engaged in the commercial manufacture of steel. While it is true that others had made some use of electrothermic methods at a much earlier day, for example Despretz, whose source of current was 600 Bunsen cells, yet Siemens' furnace must be considered the first really practical one, coming as it did after the invention of a cheap source of energy—the electric generator. Siemens' work is of particular interest because he saw the possibility of using the electric furnace for steel manufacture, and, so far as the principles are concerned, they are the same as those in actual commercial use to-day.

The growth of the Siemens electric furnace for steel-making was at first slow, for numerous practical difficulties in its working had to be overcome, but most of these have at last been met successfully by men like Héroult, Girod, Stassano and others who have modified the apparatus in various ways. Siemens in his furnace used direct current, and laid particular stress on the point that the charge should be connected to the positive side of the circuit, since it is well known that in the electric arc it is at the positive electrode the main generation of heat occurs. In the modern furnaces, however, alternating currents are used for obvious reasons, and the surface of the molten bath is covered with a layer of slag which becomes intensely heated, not only by the arc but by the current which it carries. In this way ideal conditions are obtained for refining the metal, as the steel and the molten slag between which chemical reaction is desired are intensely heated at their surfaces of contact. Moreover, the slag effectually prevents the introduction of carbon from the electrodes into the metal. The problem of regulating the electrodes automatically has also been successfully worked out by means of the well-known Thury regulator, though it would seem that this could be simplified.

There were, of course, a large number of metallurgical problems to be solved in connection with the steel furnace, but these have apparently been met successfully, and we finally have the electric furnace working alone commercially, or what is perhaps more generally important, acting as an auxiliary to fuel-heated furnaces. The most serious problems connected with furnaces of this type at the present time are those relating to electrodes and roofs. Some years ago, when the electric furnace was working on a much smaller scale than is demanded to-day, the strongest argument advanced against it was that the cost of heating by means of an electric current must of necessity be so excessive that the idea was impracticable. That, however, is criticism seldom heard to-day, for it has been found that in actual practice the furnace can be so used that the question of cost of electrical energy is by no means of the first importance. On the other hand, little used to be said about electrode cost, but now that is a most vital question, and is apt to enter into the total cost of working as a much larger item than power.

The manufacture of large carbon electrodes, say 20in. square and from 7ft. to 10ft. long, is by no means easy, and even when they are successfully made in the electrode factory they may go to pieces in the furnace. Even if they do not break there is the problem of "butts." Suppose a large electric steel furnace with the roof 3ft. away from the bath, then it is safe to say that when the electrode holder is lowered down and comes in contact with the roof of the furnace, there will be a carbon "butt" about 4ft. long which must go on the scrap pile. Apparently this serious difficulty is going to be overcome by electrodes which can be fastened end to end, so that they may be continuously fed into the furnace, and thus there will be no waste from "butts." Within the last few months there has been a good deal of work done in this direction, and the results are very promising. The electrodes are made with a circular cross-section instead of square, and have threaded sockets in the ends so that by means of threaded plugs the electrodes may be fastened together and thus fed continuously into the furnace without any waste.

This, as has been said, is promising, but has the limit of the electric steel furnace been reached as regards size? Except as regards electrodes there is no reason to believe that it has, but the 15-ton furnaces working now need electrodes about 20in. diam., and if the size is doubled and the general design is kept the same, electrodes 27in. or 28in. diam. will be required. Perhaps these can be made and can be used continuously, as described above, but the writer believes that development in this direction is a mistake, and that far better results can be obtained by multiplying the number of electrodes and keeping the size within reasonable limits. This is not merely a question of avoiding the difficulties of large electrode manufacture, but involves more efficient and satisfactory working of the furnace. It will readily be seen that the distribution of temperature in the furnace is bound to be better as we multiply the relatively small areas where the heat is generated, and this is an important consideration. The objection that is raised to this proposal is the difficulty of regulating the rate of generation of energy at the various electrodes. It does not seem that this difficulty is a real one.

The roof problem is altogether a different one. It must be remembered that the heating effect in the steel furnace is generated in an arc and in a register formed by the slag, and that consequently the surface of the slag is intensely hot, particularly where the arc strikes it. These conditions are very severe and, combined with the corrosive action of the lime which is vaporised from the slag, make the roof renewals a heavy item in the cost of electric steel.

This problem has recently been the subject of careful study in two research laboratories, with one of which the writer is connected. As a result of a great deal of experimental work a brick made of silicon carbide has been manufactured which it is believed will have a much longer life in the steel furnace than the silica brick now used. The brick is made by taking powdered or granular silicon carbide, mixing it with a suitable temporary binder, such as a solution of dextrine, moulding and then heating in an electric furnace to the temperature at which silicon carbide is formed. Bricks made in this way have been used in the roof of an experimental steel furnace in one of these laboratories and then put to the severest test possible. The bottom of the furnace was purposely raised well above the normal level so as to bring the surface of the slag as close to the roof as possible, the actual distance in some experiments being only 10in. Then the furnace was worked at double the normal rate of generation of energy so that the heating of the roof was very intense, so much so that an ordinary silica roof would melt down rapidly and be completely destroyed in a single heat. Even under these very severe conditions the silicon carbide roof stood up perfectly. Experiments have also been made in other steel furnaces and these results confirmed. The most serious objection to a roof of this kind is its relatively great cost, but if it lasts a sufficiently long time it is nevertheless economical.

Twenty-five years ago Ferranti in England and Colby in America worked on the very interesting furnaces known as the induction type. In this the secondary of a transformer consists of the metal to be melted. As in the case of the Siemens furnace, the original inventors were too far ahead of the times, and it was not until ten or more years later that any commercial application of the furnaces was made. Since then the induction furnace has developed considerably, and is now used with success in the manufacture of steel. An objection to the induction type is that its first cost is very great and certain problems connected with it become very serious when it is desired to build furnaces of large capacity. The worst of these is the very low power factor of the furnace. To overcome this objection it is necessary with large furnaces to have a generator furnishing currents of excessively low frequency. Thus, at the Völklingen Steel Works a generator giving a current of 15 cycles is used, and

* Abstract of paper read before the American Institute of Electrical Engineers.

for larger furnaces it has been proposed to use a 5-cycle current. In an experimental induction-furnace plant built by the writer's laboratories for an electric furnace company at Niagara Falls, the low power factor was corrected by using a synchronous motor as a condenser.

In Acheson's first experiments which led him to the discovery of silicon carbide (carborundum) he used a furnace of the Cowles type. It consisted of a small brick box with carbon terminals at each end so arranged that they could be moved in and out in a horizontal direction. This box was then filled with the mixture of sand and coke (clay and coke in the earlier experiments) and the terminals brought together, or very close to each other, and then gradually withdrawn as the furnace heated. It was soon observed that a more satisfactory way of constructing the furnace was to have stationary terminals connected to each other by means of a resister composed of granular carbon and then surround this with the charge. With such an arrangement it was necessary to have some means by which the voltage could be regulated so as to keep the rate of generation of energy in the resister constant throughout the run. This was found by Acheson to be a much more satisfactory way of working the silicon-carbide furnace, and by experiment he found the best dimensions for his resister. In the original small plant, where the furnaces had a capacity of about 100 kw., the generator supplied current to a great bank of small transformers so that variations in the voltage could be obtained by suitable connections of the secondaries. When, however, a plant was established at Niagara Falls, using furnaces of 750 kw., the problem of varying the voltage at the furnace terminals became important. This was solved by the construction of a large induction regulator to be used in the secondary circuit of the transformer which stepped down the primary circuit of 2,200 volts to 160 volts. The induction regulator then made it possible to vary the electromotive force by 60 volts on either side of this, so that at the furnace terminals the total range was from 100 to 220 volts. In working with a furnace having a carbon resister, the resistance when starting is high, so that, to save time it is necessary to start the furnace with a high voltage. When the resister becomes hot its resistance progressively decreases and the voltage must then be decreased to keep the rate of generation of energy constant. If this is done in a series of steps the results are not satisfactory, for when the maximum kilowatts are reached and the voltage is lowered one step the kilowatts are decreased proportionately, and in large furnaces it is a long time before the resistance drops to the point where the desired rate of generation of energy is again reached. This is a most inefficient method of working and the consequent loss will more than pay the interest on the cost of suitable apparatus for regulating the voltage.

In any furnace in which the charge surrounds a resister heated by means of an electric current, it is obvious that the important consideration is the rate of generation of energy per unit surface of the resister. The surrounding charge, or whatever it is desired to treat, can at a definite temperature absorb heat at a definite rate. Therefore, if it is desired to preserve the charge at a definite temperature it is necessary to generate the heat only so fast as the charge will absorb it. In other words, it is necessary that the watts should be a certain definite amount per unit surface of the resister. The knowledge of the absolute value of the temperatures in such furnaces as those used in making silicon carbide is very scant, although some excellent work is now being done on this subject; but from the data obtained experimentally, and the theoretical considerations of the working of such furnaces, it is possible to calculate relative temperatures with considerable accuracy.

This was well illustrated in the experimental work done by the writer in the difficult problem of making what Acheson called "siloxicon." This substance is formed by the reduction or partial reduction of silica and is combined in some way with carbon. The great difficulty in making the material is due to the fact that at a temperature very slightly above that at which the reduction of silica by carbon begins, the process goes too far and the well-known crystalline silicon carbide is formed. In order to calculate the dimensions of a resister suitable for making the material the only data available were those which could be obtained from a study of conditions in the silicon-carbide furnace. Without going into details it is sufficient to say that working in this way a furnace was soon designed which made large quantities of "siloxicon" without the formation of any serious quantity of crystalline silicon carbide.

The object in devoting so much consideration to this subject is because it illustrates in a marked manner the comparative ease with which electric furnaces can be adjusted to delicate temperature conditions. This is, of course, well known as regards small laboratory furnaces, but what we are considering now is a furnace about 30ft. long, 12ft. wide, and 6ft. high, having a capacity for a charge of about 60 tons.

The greatest progress in the electric furnace since Siemens' time has been in the arc furnaces of the kinds he used; in the induction furnaces of Ferranti and Colby; and in the resistance furnace of the Cowles type; but so far as the furnace depending on the use of a heating resister, other than the charge, is concerned, there has not been any great advance as regards apparatus of large capacity. The explanation of this is found in the structural difficulties involved. It is believed, however, that those can be overcome, and, moreover, that it is well worth while spending considerable effort in this direction. In the laboratories with which the writer is connected much time has been devoted to a study of this type of furnace, and more or less successful furnaces worked out. This kind of furnace, for example, lends itself very readily to a form of apparatus which is bound to be developed sooner or later where the heating is accomplished by means of fuel as well as the electric current. This has been done with success in furnaces on a large scale where the preliminary heating is carried on by means of fuel until a temperature is reached where it becomes economical to use the electric current to get the higher temperatures desired. Moreover, in such furnaces we may usefully employ nearly all the electric current by jacketing with burning gases, which eliminates nearly all radiation from the interior of the furnace by supplying the inevitable heat losses from fuel rather than electricity.

The question of the loss of heat through the walls of electric furnaces is a matter that is now attracting a good deal of attention, for its importance is very great. The writer has recently had occasion to give this matter careful consideration owing to the inefficient working of an electric furnace designed for some special smelting work. The testing of this furnace showed that the heat losses amounted to 50 per cent., but merely covering 25 per cent. of the outer surface of the furnace with a moderately good heat insulator reduced this loss nearly 20 per cent.

Before closing the remarks on this type of furnace it may be of interest to note some experiments recently carried out with an electric kiln at the writer's laboratories. The kiln is the invention of Mr. John L. Harper, and is of the continuous-channel type. Two long channels run parallel to each other, and through each of these passes a train of trucks in opposite directions. The centre part of the kiln is heated electrically. With this arrangement the trucks with their contents passing from the high temperature part of the kiln give up their heat to the trucks going to the high temperature part. Theoretically, with an arrangement of this sort, all that is required of the electric energy is to supply the heat losses from the kiln. Various experimental furnaces of this kind have been built, the chief object in view being a study of the structural features of the kiln, such as the best form of resister, refractory linings, &c., also tests of the control of temperature, maximum temperature available, control of atmosphere, heat insulation, &c. The kiln was used for various purposes, but the principal experiments were made on porcelain with the production of "biscuit" and glazed ware. The control of temperature was found to be very good, and the kiln was extremely simple to work, requiring very little attention.

Fatal Winding Accident at a Colliery.—An accident occurred on Monday last at the Bargany coal mine, resulting in the death of a workman. While some men were engaged in sinking operations, a "kettle" heavily loaded was being drawn up the shaft, when the wire rope broke and the "kettle" was flung down the pit, fracturing the base of the skull of the deceased in its descent.

RECIPROCATING SAWING MACHINES.*

BY CHARLES WICKSTEED.

Historical.—The saw is one of the very earliest tools known to have been used, and is, in fact, the earliest tool that has been traced in Egyptian history. It was first found in the form of a notched bronze knife in the 3rd Dynasty or about 5,000 years B.C. (A), Fig. 1†, and was followed by larger toothed saws in the 4th to 6th Dynasties, which were used by carpenters; but there are no dated specimens until the 7th century B.C., when the Assyrians used iron saws, as shown

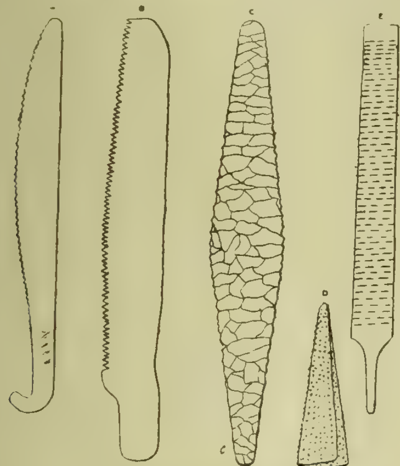


Fig. 1.—Ancient Egyptian Tools.
A. Notched Bronze Knife. 3rd Dynasty. 5000 B.C.
B. Assyrian, Iron. 7th Century B.C.
C. Flint Knife.
D. Rasp made of Bronze punched and coiled round.
E. Straight Rasp, Iron, Assyrian. 7th Century.

at (B). The first knives on record were made out of flint, and were, in fact, saws with minute teeth (C). They must have been used for cutting up animals, as the teeth would break away even on soft wood. Rasps, which are but a form of a saw, were first made of sheets of bronze punched and coiled round, as shown in (D), but the Assyrians in the 7th century used the straight rasp made of iron exactly like the modern type (E). Coming down to modern times, the saw is possibly used more than any other tool. It has taken three distinct forms, both for the working of wood and metal—the straight saw, which is simply a development of the first toothed knife, the band saw, and the circular saw.

Hack Sawing Machines.—The author proposes in this paper to discuss the merits of the straight-blade reciprocating saw for metal work, and to point out that, although great pains have been taken to bring to perfection the band and circular type, curiously enough the straight-blade reciprocating saw-

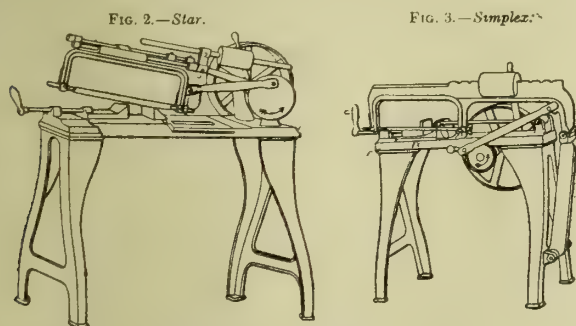


Fig. 2.—*Star.* Fig. 3.—*Simplex.*

ing machine has been, comparatively speaking, neglected. The simple fact that, with a few exceptions, the cost of the hack sawing machines has in former years been only from £5 to £10 against a much higher cost for the other types, fully attests the truth of this statement. Primitive blades sold at about 3d. each and primitive machines sold for a few pounds were good enough for this system. The author thinks that it was Millers Fall Company, Mass., who first brought out the hack sawing machine, which is known as the "Star," Fig. 2.

* Paper read before the Belfast meeting of the Institute of Mechanical Engineers, July, 1912.
† "Ency. Brit.," Vol. IX. (11th ed.), p. 71, Figs. 17, 45, 46, and 48.

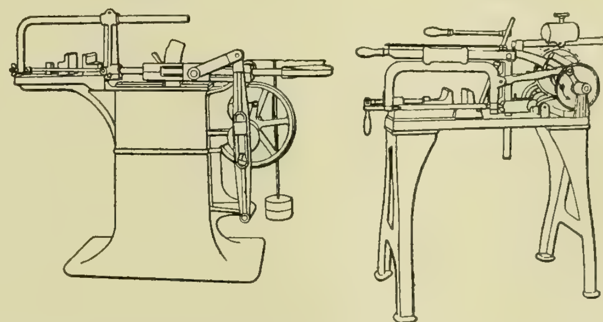
This is the crudest and lightest possible device for working a saw backwards and forwards by power instead of by hand. It is not curious that a start should be made in this way, but the curious part is that this machine, in all its essentials and with all its faults, prevails up to the present time. The connecting-rod was made of wood, the old hand-saw bow has been maintained intact, and the guides were of the most elementary character.

The next hack sawing machine that was introduced was, the author believes, the style known as the "Simplex," Fig. 3. This is more elaborate and heavier, the old hack saw frame giving way to something stronger. It was brought out by Mr. Hoefer and proved very successful. These two machines were the forerunners of all the present hack sawing machines.

Another very early pattern of hack sawing machine was the "Eureka," Fig. 4, which was made by Messrs. G. Thompson, Son, & Co., of New Haven, Conn. This is a far more mechanical and carefully-designed structure; it has a solid base, and a real attempt was made to guide the saw straight, the thrust is in direct line and the upper guide being made to extend, so as to admit the large variation in the length of the blade being used. This was a magazine saw, a long blade like the band saw being coiled up and brought out for use as the working part became worn up. The coil contained 25ft.

One of the latest machines brought out is the "Milford," Fig. 5, which is a carefully-designed tool, and is in great demand. It is fitted with a quick return and a clutch device for lifting the blade free of the work on the idle or return stroke. It has a geared drive of 4 to 1 and an automatic stop. In the author's opinion, these four designs fairly illus-

Fig. 4.—*Eureka.* Fig. 5.—*Milford.*

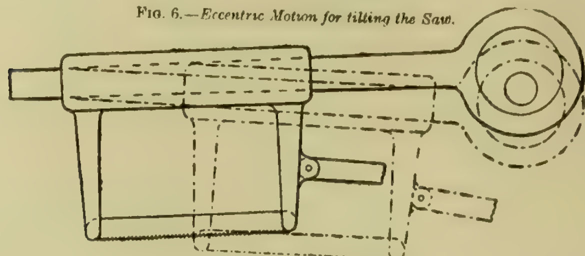


trate the progress of the original type of hack sawing machine up to a recent date, although many others might be mentioned, for instance, the "Racine," which is a compact and strong tool, and the "Marvel," a strong, complicated machine with a positive feed.

Messrs. Herberts, of Manchester, were one of the first firms who seriously took this matter in hand, with the view of making altogether stronger machines to do the work quicker and to take larger sections. They made saws of a capacity hitherto commercially unknown, the largest being capable of taking 18in. by 30in. They also introduced amongst other things an automatic feed for the work, but the most important feature of their machines was the eccentric motion given to the fulcrum of the saw frame, shown in Fig. 6, where, every 20 strokes or so, the eccentric on which the fulcrum of the frame is pivoted moved round slightly, thus putting the saw at a different angle to its work and bringing it on a very obtuse corner. By this means it was always working on a comparatively small surface, and it thus became much easier to saw heavy sections. The author believes that Messrs. Herberts were able to cut bars much quicker than formerly. For instance, a 4in. bar could be cut in 20 min., compared with an hour taken by most previous machines. The only disadvantage in this method is, in the author's opinion, that when first the eccentric is moved the effect on the saw is rather rough, but as quick work is often of greater importance than too great economy in saw blades, the merits of the machine were rapidly appreciated. The author thinks that this firm was the first to use a stronger and better blade, and they were backed up by the Sterling Company, who used tungsten steel.

Messrs. Herberts have recently constructed a tool in which the blade is set at an angle to the guides. This causes further pressure on the blade while cutting, and takes the place of the weight to that extent.

Messrs. Holroyd & Co., of Milnrow, also introduced an excellent machine for rapid work with the same object in view as Messrs. Herberts had, the difference being that in the case of Messrs. Holroyd's machine the bar turned round a little every several strokes, thus representing a small surface to the saw, as Messrs. Herberts did, with their eccentric motion. The advantage of Messrs. Holroyd's system was


FIG. 6.—*Eccentric Motion for tilting the Saw.*

that, since the bar was continually turning round, it was difficult for the saw to run, and the work would be approximately as true as that produced in a cutting-off lathe.

Advantages.—(1) The comparatively low cost of the machine and blade, and the fact that the blade can be made any temper to suit the work.

(2) In comparison with the circular saw, it will cut any depth that the frame which holds it will admit of. Extra depth does not necessitate extra cost of blades, and it will cut any length within 6in. of the length of the blade. A circular saw, taking the boss in consideration, will not make a cut much deeper than one-third of its diameter, and for every extra inch in depth the saw must be increased 2in. and 3in. in diam. It is a most expensive and cumbrous tool, necessarily fairly thick and exceedingly difficult, if not impossible to get quite hard, and if made quite hard is, of course, liable to break up.

(3) In many cases the band saw must be cut in order to be threaded through the work and, like the circular saw, is almost impossible to get it quite hard; moreover, it is dangerous to use if it is hard.

(4) Another advantage of the straight blade over the circular saw or a lathe cutting-off machine is the narrowness of the cut, say, $\frac{1}{16}$in. instead of $\frac{1}{4}$in. This, so far as the circular saw is concerned, at anyrate, reduces the power taken in exact proportion to the width to be cut, and in both cases it usually saves material enough to pay the whole operation. That is to say, if the material saved by the narrow cut as against the wide one is taken into account at the end of the

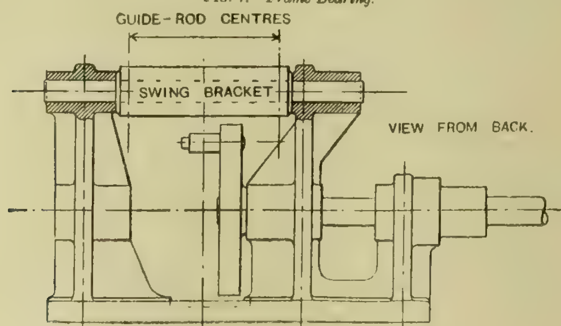


FIG. 7.—*Frame Bearing.*

day, sufficient material will have been saved to pay for the whole cost of cutting, including establishment expenses.

(5) The power taken is about one-fourth of that taken by a circular saw. One unit will cut 80 super. square inches, which is equivalent to 11 bars of 3in. diam. or three heavy section girders, 20in. by $7\frac{1}{2}$in.

When once convinced that the straight-blade reciprocating machine had great theoretical advantages over its competitors—the circular and the band saw—it did not take very long to discover the principles on which it must be made:—

(1) The blade must be kept absolutely firm and perfectly square with the work.

(2) It must be strong enough to stand all the weight that the teeth will take without breaking.

(3) The blade must be made of the highest possible quality of steel with the best cutting edge that is practicable.

(4) The machine must be well designed and work the blade without spring or vibration.

(5) Since the pressure on the blade must be considerable, an absolutely reliable release on the return stroke must be provided. In connection with this, the author has found from experiments that, unless the weight was heavy, it made little or no difference whether the blade was released on the return stroke or not, but with a very heavy weight the blade would be quickly destroyed.

Taking the points just mentioned *seriatim*, the blades have not been brought to the high quality now described without a great deal of pains and trouble on the part of the makers, who have been kind enough to assist the author in this respect. The points which appear to be fairly established are:—

(1) For ordinary work the coarse-pitch tooth, not less than 10 to the inch, is the best. They cut better, they clear themselves better, and there is better opportunity to give side clearance, which is specially necessary in the deep blades necessary for heavy machines.

(2) To make the blade strong enough to take the weight that the teeth will stand, it is not necessary to do any special tempering for this purpose. If the temper is right for the teeth, it is right for the back of the blade.

(3) Extra strength must be obtained, not by extra thickness but by extra depth. Extra thickness does not help in any way. If the blade is 20 per cent. extra thick it requires

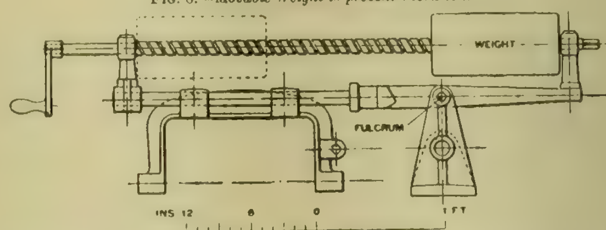


FIG. 8.—*Movable Weight to prevent Vibration.*

exactly 20 per cent. more weight put on to get through the work in the same time. Theoretically, the thinner the blade the better, but in practice the deep blades must be made thicker for convenience of manufacture, because makers find it too difficult to harden deep thin blades absolutely straight, and it is evident that the deeper the blade the more difficult it is to keep the clearance. The blades used by the author vary from $\frac{3}{4}$in. to 2in. in depth and from 19 to 16 wire-gauge thick.

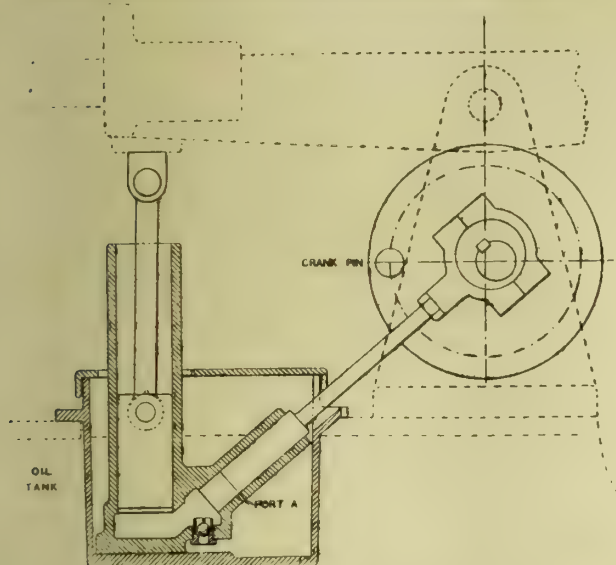
(4) The greatest weight that a tooth will take without injury must be ascertained, and the blade must then be made strong enough to take it. This weight the author finds at present to be about 7lbs. per tooth or 70lbs. per inch. A weight of 210lbs. is therefore put on a 6in. machine, which enables it to use practically the full capacity of the blade up to a 4in. round bar.

As the machine gets larger the proportion of weight is increased. Thus in a 15in. machine 700lbs. is put on, so that the machine will use the full capacity of the blade when sawing a 10in. surface. The proportion is increased in this way because it is presumed that the 6in. machine, for instance, will principally be doing smaller work, and that the larger machines are intended for large work which it is important to get through as quickly as possible.

Design of Machines.—After having said this much about the blades, it is hardly necessary to point out that a machine very different from those usually employed must be designed to work them. Most of the old designs were more useful as warnings than examples. In getting out a new design, the author's ambition was to make a reciprocating sawing machine in the form of a first-class machine tool, on simple and sound mechanical principles that would utilise all the duty that a high quality straight blade was capable of taking. One of the greatest faults of the machine so far in use is that,

following the example of the first machine that was made, the guide-frame is almost universally pivotted on the crank shaft, generally by a narrow bearing, thus ensuring liberty to begin with, which daily increases with wear. In this way was the first essential of a good machine missing at the outset. With a loose guide the saw would run, make bad work, and break the blades. To avoid this fundamental defect, the guide-frame is pivoted on perfectly independent bearings, substantial and wide apart. These bearings have no other work than to guide the frame, and there is practically no wear whatever, Fig. 7. It was found necessary to stiffen the machine in every direction. The bed was made much wider, a bearing being thus given for the bar on both sides of the saw, the guide bars were placed wide apart, all the bearings brass-bushed and ample, and in the case of the larger machines a vice was provided on both sides of the blade.

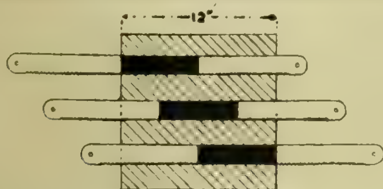
FIG. 9.
Pump and Ram to lift and lower the Saw accurately at the extremes of stroke.



Weights were increased until a 6in. machine weighed 5½ cwt., and a 15in. machine 25 cwt. These weights were found necessary to make the machine perfectly firm and free from all vibration. Since the weight used on the blade was so heavy, it became necessary to adopt a convenient method of applying this from zero upwards. This is done by sliding a weight on a bar which runs from the extreme end of the frame to a point well behind the fulcrum of the swing bracket, in which position it balances the weight of the guide bars and frame. In the heavy machines this weight is adjusted by a quick pitch-screw, Fig. 8.

Having such a heavy weight to deal with, it was next necessary to prevent the breakage of the machine in case the blade should break, and so long as the usual small boy was to manipulate this machine it also became necessary to lift the weight by power. A perfectly reliable release was also required on the return stroke of the blade. This latter is a difficult or impossible thing to provide for satisfactorily by purely mechanical means, as the plane of the saw varies at every stroke, so that a rack-and-catch arrangement is unsuitable. The clutch principle used on some machines is also unsatisfactory, as it constantly requires a nice adjustment which is quite beyond the capacity of the boy in attendance. Experiments have shown that it was essential that the saw should be lifted off its work and put down again accurately at the extremes of the stroke. If this be not done, either the output is seriously interfered with or the blade is injured. Ultimately to deal with all these points, a 4-function hydraulic ram (to be described later) was used on all the larger machines. This was first out in the form of the simple ram, as shown in Fig. 9. Here an eccentric set in time with the crankpin on the crank shaft works a little plunger in connection with the dashpot. This plunger comes down and closes the little port A exactly at the end of the stroke, thus gently lifting the frame sufficiently off its work on the return stroke and letting it gently down again, and, as soon as the working stroke begins, leaving the full weight on the blade. There are no complications and no wear in this device, as both pistons are simply made a good fit and worked in oil. A foot-valve is provided to let the oil in when the frame is lifted by hand. It was found to perform perfectly the function it was designed for.

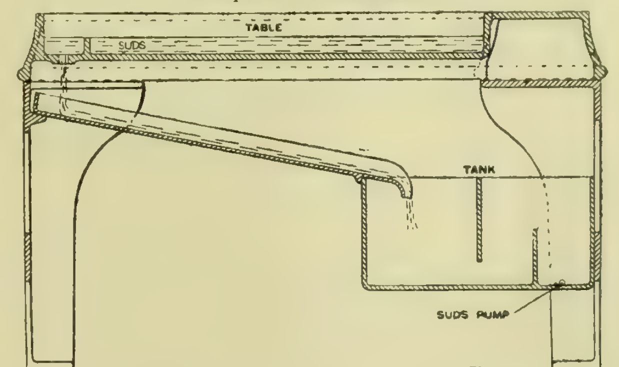
FIG. 10.
Three positions of a Saw with 6in. stroke cutting through a 12in. block.
The black portion is that which always remains in the saw cut.



Modifications very quickly followed to make it useful for other purposes. The port was made small enough to convert the largest cylinder into a dashpot and thus make it impossible for the frame to fall, as it could only be lowered as fast as the oil could be pressed through the small hole, about $\frac{1}{32}$in. diameter in the case of the smaller machines. Soon after this, the ram was made to perform four functions by the introduction of a 4-way cock.

It is difficult to follow the exact action of this ram, but it will perhaps be sufficient to point out that this pump is provided with a 4-way cock with ports so arranged that when the handle is in the horizontal or working position it relieves the blades on the return stroke. When upright it lifts the whole frame right off the work to any required height, the relief port being provided to prevent it lifting too far. When in the third position it holds the frame in the position it happens to be in. When in the fourth it lets the frame gently down whether the machine is standing or not. This last position is useful, as in its simple form this ram can only let the frame down when the port is uncovered, which it seldom is when the machine is standing.

FIG. 11
Pump and Tank below machine.



The stroke in the author's machine is from 5in. to 8in. The longer stroke adopted in the larger machines was not found necessary to get rid of the swarth, but simply because it was found advisable to reduce the strokes per minute, as the lengths of the frames increased, the momentum given by the small relief-lift becoming too much.

The question of the relative length of the blade to the stroke and diameter of the bar is interesting. A long stroke should be avoided, as it entails a correspondingly long saw blade as well as a more cumbrous machine. If there is no lift on the return stroke the stroke must be as long as the section cut, in order to get rid of the swarth. Fig. 10 shows a 12in. section being cut with a machine having only a 6in. stroke. The middle part of the blade (shown black) has no opportunity of getting rid of its swarth, and will therefore take the greatest part of it backwards and forwards. With a sufficient lift on the return stroke, however, the swarth is dropped and raked 6in. forward on the cutting stroke, and it is thus only necessary to make the teeth deep and large enough to hold the swarth created in two strokes.

The lubricant used for saw blades is soap suds, and great attention has been paid to the pump and tank connected

therewith. The fact that the swarth made by the saws is exceedingly fine and that it is very much more difficult to make a pump to wear well with the suds than it is with oil, necessitates very careful provision to keep the swarth away from the pump and to make the pump as durable and as easy to repair as possible. Fig. 11 shows the arrangement of tank and connections. It will be seen that the suds are first collected by a recess in the bed, and are drained at the front end which is farthest away from the swarth, which is carried back by the blade which works on the return stroke.

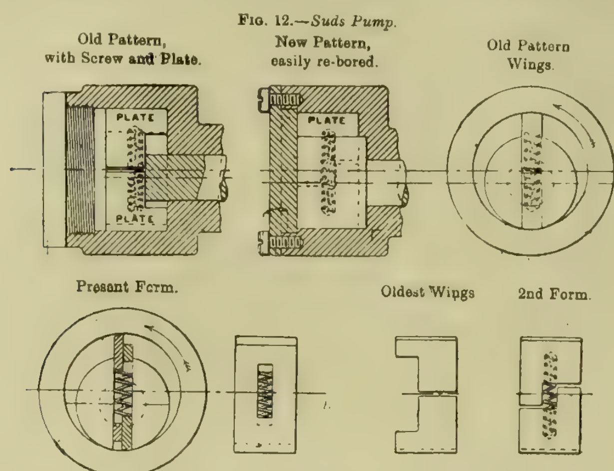


Fig. 12.—*Suds Pump.*

The suds are then conveyed through an open trough to a tank placed at the back end of the machine. This tank is divided by two weirs (if they may be so called) into three compartments. The first weir comes to the top of the tank, leaving a space of about 1in. at the bottom for the suds to pass through into the next chamber. This is done to prevent very light swarth on the top of the suds being washed over. The suds then go over the top of the second weir into the pump chamber. In this way it is seen that the swarth has four distinct opportunities of being separated from the suds, and that it is almost impossible for any grit finally to enter the pump.

Fig. 13.—Single Sawing Machine.

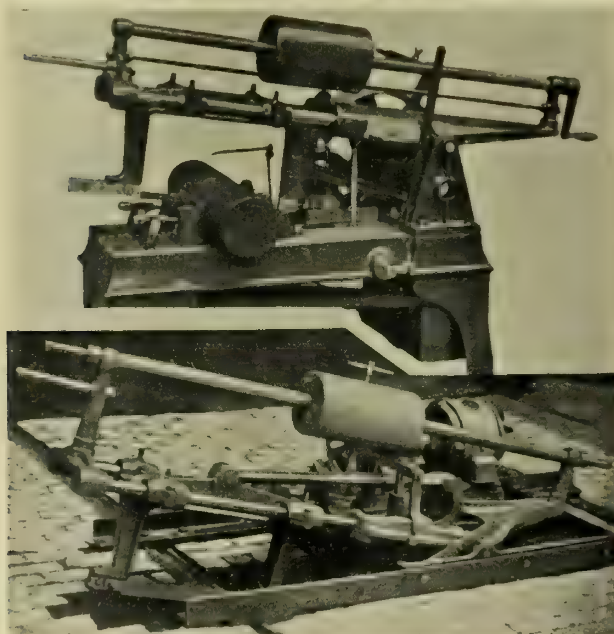


Fig. 14.—Single Sawing Machine for Cutting Tramway Rails.

Pumps.—The first thing that appeared important in connection with the pump was that it must be placed under the level of the water to avoid constant priming. Wing pumps were adopted as being the most satisfactory, but the best the author could obtain were of such a construction that they would not wear well or long with suds. The simple pump ultimately adopted is shown in Fig. 12. In this pump a bywash is provided, not with a separate valve, but simply by making the wings of the pump taper against the pressure so that, when a full discharge is not required, the pressure of the suds will press these little wings back. The cover, instead of being screwed in, as is often the case, is simply fastened on with screws so that the barrel can be re-bored. But perhaps the most important feature of this design is that both wings go right through the head of the spindle, and thus get an ample bearing. In these wings there are two little slots of such a length that one spring put in the middle will press up the wings on each side. The advantage of this is obvious as compared with the old method where the wings met in the middle, thus leaving but a very little bearing. The gradual wearing of this bearing caused friction and the destruction of the pump. The spindle of the author's pumps

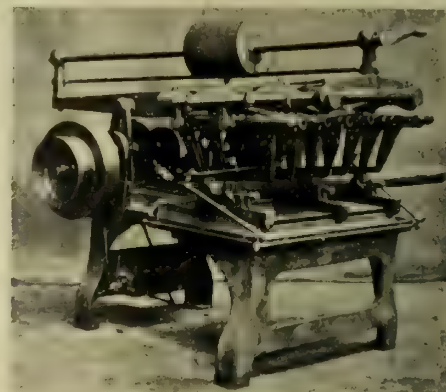


Fig. 15.—7in. Multiple Saw for Cutting Blanks from ¾in. thick up to the Capacity of the Machine.

is case-hardened. The new pattern of pump has been found to be very efficient.

Results.—The result of all these improvements is that sawing can be done practically true, say, to a hundredth part of an inch in a 6in. bar, and mild steel can be cut at a speed, roughly speaking, varying from 1in. to 2in. square per minute. The breakage of the blade is exceedingly rare, and those of the best quality will often last several days.

The machines are made in several forms. The single sawing machine, shown in Fig. 13, is constructed for sawing pieces of large dimensions quickly and correctly. Fig. 14 shows another variety, a machine for cutting tramway rails in position. This machine rests upon two angle-irons which, in their turn, rest upon the two rails. It is only necessary to disturb the pavement for the frame. The main features of the machine are standard. It makes a straight clean cut through the rails, no matter how hard, in about 20 minutes, and one blade will make from about 12 to 20 cuts before it is worn out. The multiple saw, Fig. 15, and Fig. 16, specially designed to cut off blanks for dies and

Multiple Saw.

Fig. 16.—*For cutting blanks from ¾ in. thick up to the capacity of the machine.*

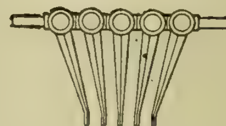
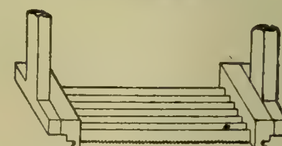


Fig. 18.—*Rack Arrangement for cutting blanks from $\frac{1}{16}$ in. to ¾ in. thick.*



similar duplicate work. By a rack arrangement, Fig. 17, and Fig. 18, these blanks can be cut as thin as $\frac{1}{16}$in.; with the more usual arrangement of adjustable frames, shown in Fig. 15 and Fig. 16, they can be cut from ¾in. thick to the capacity of the machine.

What is called the shaping machine, Fig. 19, and Fig. 20, is another variety. This machine is provided with a table like a shaping machine on which the work is placed. By this means the work can be brought to the required position under the blades. Two blades are provided which can conveniently be adjusted in alignment from ½in. apart to the full capacity of the machine, usually about 5in. It is more particularly useful for cutting out joints of all sorts, splitting brasses, and so on.

Another variation of pattern is the runner saw, Fig. 21. This is specially designed to cut runners off steel castings, which are bolted on the front or the side of the table. The whole head is made to traverse a foot sidewards

so as to reach the runners; it can also be lifted and put forward on the bed if necessary. The saw is brought on one side of the guides so that it will cut runners quite flush to the casting where the saw holder does not foul. In the few cases where it would foul, it would cut flush within $\frac{3}{16}$in. The

FIG. 19.—SHAPING MACHINE SAW.

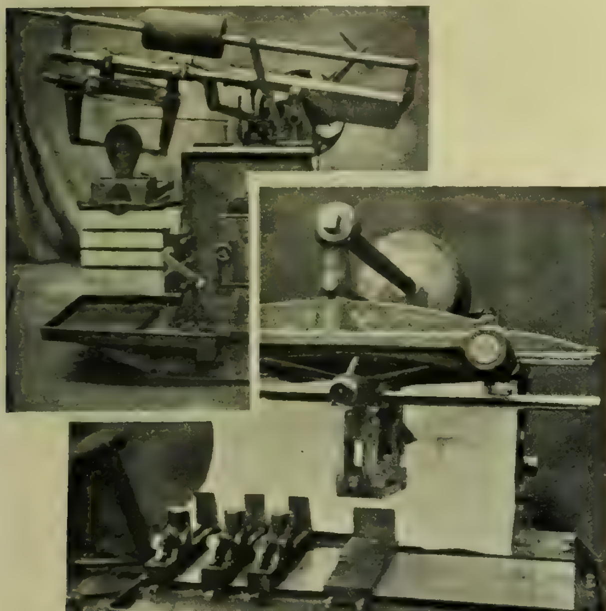


FIG. 17.—MULTIPLE SAW RACK ARRANGEMENT FOR CUTTING BLANKS FROM $\frac{1}{16}$IN. TO $\frac{3}{4}$IN. THICK.

hard blades that can be worked with this machine make this method compare favourably in many ways with the circular or band-sawing machines.

Another variety which is in course of construction is a machine for sawing out webs of crank shafts. Here, as in the shaping machine, there are two blades, but the table is stationary, the crank shaft being bolted down on blocks to the correct position under the blades. A horizontal blade is also provided for cutting out the bottom of the crank shaft. This third horizontal blade works independently of the two vertical ones; the frame of this is constructed to hold a square file as well as the saw blade. The operation is as follows: The crank shaft must first have one hole drilled in it, say, $1\frac{1}{4}$in. or $1\frac{1}{2}$in. diameter. It is then bolted down on the blocks in position underneath the two vertical blades, and these

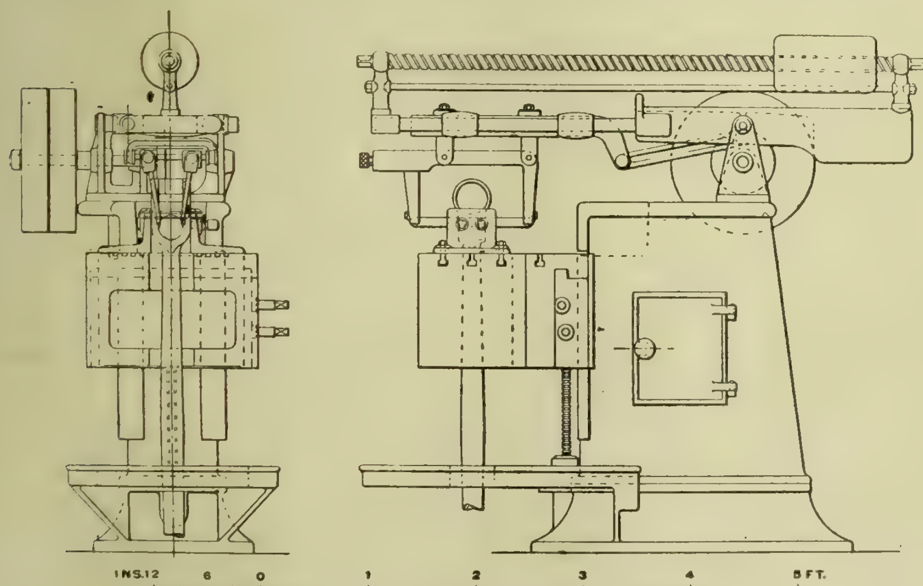


FIG. 20.—SHAPING MACHINE SAW.

blades are set to work. The file is threaded through the hole and attached to the horizontal frame and the hole filed out approximately square at the bottom. To accomplish this, the lower frame is attached to a table which can be raised and lowered by hand. There is also a hand-traverse in the horizontal direction. The table is provided with a counterweight so that the filing out of the hole can easily be manipulated by the two hand-traverses mentioned. After the hole is filed sufficiently square, an operation of a few minutes, the file is withdrawn and the blade threaded through instead. The horizontal blade is then put automatically to work. It is provided with a 4-function automatic ram, like the other, and works independently and precisely on the same system. There is usually so much less to saw horizontally than there is to saw vertically that the horizontal work will probably be finished some time before the vertical. When this is the case, the horizontal blade is removed and the frame drawn out of

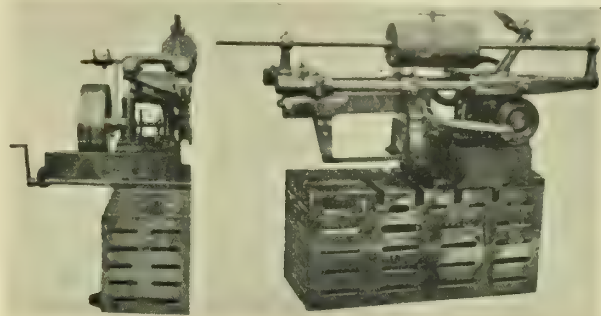


FIG. 21.—SAW FOR STEEL CASTINGS.

the way of the vertical saw before they approach near enough to foul. It will be thus seen that in the manipulation of the horizontal blade there is no time lost. A 9in. by 9in. crank shaft web may thus be sawn in 60 minutes to an accuracy of $\frac{1}{64}$in., using about 2 h.p. The outside of the webs can also be sawn at another operation, thus saving much valuable time afterwards on an expensive lathe.

In conclusion, the author would like to state that he has simply been trying to trace the development of a most useful tool so far as it has gone. He is not of opinion that anything like finality has yet been approached, but he believes that in rapidity of work, in the endurance of the blades, and in the size of the machines, the reciprocating straight-blade sawing machine is still in its infancy.

MATERIAL FOR TURBINE BLADES.

IN an article in "La Technique Moderne," and translated in the August Proceedings of the American Society of Mechanical Engineers, P. Breuil deals with the metals used for the blades of continental designs of steam turbines.

For turbine blades, Zoelly uses steel with 5 per cent. nickel. Brown-Boveri, who use a large number of stages, with small falls of pressure, and consequently small velocities of steam, use a special bronze with a coefficient of safety of 15 to 20; the blades do not appear to be subject to wear. The German General Electric Company, which manufactures Curtis turbines, makes the blades out of a special bronze or of steel with a high percentage of nickel, with caulking of a softer metal. Rateau, after unsuccessful experimenting with steel with 25 per cent. nickel, uses now steel with 5 per cent. nickel, while Rey, of Harlé & Cie, prefers steel with 32 per cent. nickel.

Enquiries from various French manufacturers of special steel have shown a great diversity of opinion as to the contents of nickel, but it does not appear to the author that any one of them knows just what influence more or less nickel in the steel will have on the behaviour of the metal in a turbine blade. Table I. gives a resumé of the data which the author collected with respect to bronzes. Of these the composition is given only for the "Durana" bronzes manufactured by the

Dürener Metallwerke, Düren, Germany, viz., the first kind 72 per cent. copper and 28 per cent. pure zinc, and the second kind 85 per cent. copper and 15 per cent. manganese. The composition of the Monel metal is given as 70 per cent. nickel, 29 per cent. copper, and 1 per cent. iron. Like other bronzes, the Monel metal softens considerably at temperatures above 300° C. (572° Fah.), and has a relatively low elastic limit, but has the advantage of being little subject to corrosion.

The author calls attention to the fact that on the side of the admission of steam the first blades work in high temperatures, with steam at great velocities and dry; the blades further back are subject to lower temperatures and lower velocities of steam, but the steam is wet, and there is besides the friction of mineral particles carried away by the steam. The guide blades are stationary, and are not subject to the action of centrifugal forces like the rotor blades. It appears therefore that different metals ought to be used for each of these three classes of blades, but in all cases the metal used must possess great resistance to chemical and mechanical corrosion, and be easily machined by ordinary shop processes. As to chemical corrosion of metals by hot steam there are practically no reliable data. From investigations of the action of salt water on metals it would appear that aluminium and manganese bronzes and Monel metal would give good results, but it is quite possible that chemical corrosion is altogether very slight as compared with physical, and the material used ought to be chosen on the basis of resistance to the latter, with respect to which nickel steel appears to have very high qualities with its breaking strength of 60 kg. (80,000lbs. per square inch), elastic limit of 40 kg. (57,000lbs. per square inch), hardness 180, and elongation 20 to 22 per cent. It is moreover naturally hard, not brittle, and comparatively cheap. There are no data as to its probable behaviour at high temperatures, but having a low percentage of nickel it would probably behave like other steel, and would reach the minimum of its elastic limit and elongation at about 300° C. (572° Fah.), without, however, becoming brittle. Vickers-Maxim make their turbine blades of laminated bars with a steel core and nickel surface, the nickel layer being only a fraction of a millimetre thick.

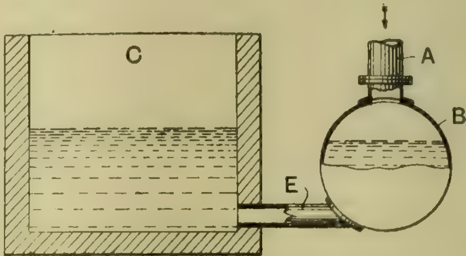
TABLE I.—*Strength of Metals Used in Turbine Construction.*

Metal.	Elastic Limit.		Breaking Strength.		Elongation Per Cent.
	Kg. per Mm.	Lbs. per Sq. In.	Kg. per Mm.	Lbs. per Sq. In.	
30 per cent. nickel steel ...	50 to 60	71,000 to 86,000	60 to 80	86,000 to 113,000	40 to 30
5 per cent. nickel steel:					
(*a*) annealed	74	105,000	77·5	110,000	36
(*b*) tempered at 800° C. (1,472° Fah.) and then annealed at 600° C. (1,112° Fah.)	90	128,000	104	158,000	9
Brass (67 per cent. copper and 33 per cent. zinc) ...	—	—	31	43,000	55 to 60
Brass (70 per cent. copper and 30 per cent. zinc) ...	—	—	28	40,000	50
Aluminium bronze BAT2..	—	—	55 to 60	78,000 to 86,000	40 to 45
Rubel bronze:					
290° C. (554° Fah.)......	18	25,600	34·19	49,000	43·5
485° C. (905° Fah.)	13·7	19,500	20·44	29,000	11·9
Durana:					
100° C. (212° Fah.)	54	77,000	57	81,000	8·5
300° C. (572° Fah.)	35	50,000	38	54,000	30
400° C. (752° Fah.)	12	17,000	20	28,500	75
15 per cent. manganese bronze:					
100° C. (212° Fah.)	58	82,500	63	90,000	10·5
300° C. (572° Fah.)	52	74,000	58	82,500	21
400° C. (752° Fah.)	33	47,000	38	54,000	68
Monel metal annealed:					
20° C. (68° Fah.)	24·1	34,000	55·1	78,000	34·5
300° C. (572° Fah.)	19·4	27,500	30·7	43,500	23·5

Examination for Smoke Abatement Inspectors. — For some time the Council of the Royal Sanitary Institute has been urged to arrange an examination for smoke inspectors, and after very carefully considering the matter, it has decided to establish an examination in this subject. Full information may be obtained from the Secretary, the Royal Sanitary Institute, 90, Buckingham Palace Road, S.W.

EXHAUST STEAM ACCUMULATOR.

THE Maschinenbau Aktiengesellschaft Balcke, of Bochum, Germany, have patented the arrangement of exhaust steam accumulator, shown diagrammatically in the accompanying cut. Two vessels containing water or other suitable liquid are employed, whereof the one vessel is connected with the exhaust from the primary engine, and also with the steam supply to the secondary engine, whilst the other vessel is connected to the first in such manner that variations in the level of the liquid in the first-mentioned vessel, due to variations of pressure therein consequent on variations in the supply or delivery of exhaust steam to or from this vessel, will produce inverse variations in the level of the liquid in the second vessel, the liquid in both vessels constantly tending to assume the same surface level. Referring to the cut, B and C are two vessels containing a body of water or other suitable liquid which partially fills them both, the vessels being connected together by means of a pipe E at a level below the lowest working level of the liquid in both vessels, so that the liquid in both vessels will constantly tend to assume the same surface level. Exhaust steam from



EXHAUST STEAM ACCUMULATOR.

the primary engine enters the vessel B by way of a pipe A, and steam is led from this vessel B to the exhaust turbine or other secondary engine, either by means of a branch from the pipe A or by a separate pipe connected to the vessel B. The vessel B, except for the necessary connections, is closed, whilst the vessel C may be open to the atmosphere. If the exhaust steam from the primary engine exceeds the requirements of the secondary engine, the excess will enter the vessel B and will force liquid therefrom into the vessel C, the level of the liquid in the vessel B being consequently lowered so that the storage capacity of this vessel is increased whilst a head of liquid is created in the vessel C relatively to that in the vessel B. If, now, the primary engine stops working, and steam is drawn from the vessel B (*e.g.*, to supply the secondary engine) liquid will return from the vessel C to the vessel B owing to the head of liquid in the vessel C.

ANOTHER TANK LOCOMOTIVE DERAILMENT.

FOLLOWING the reports of the railway accidents from derailment of tank locomotives on the Dublin and South-eastern and Lancashire and Yorkshire Railways, on which we commented in our last issue, comes a report by Major Pringle on another derailment accident which occurred between Roslin and Loanhead on the North British Railway on the 2nd ult., and resulted in the engine being overturned and the fireman killed. In the two previous cases the engines were of the 4-wheeled coupled tank type fitted with a leading and trailing pair of wheels. In this case again the engine was of the four-coupled-wheeled tank type, but though fitted with a bogie, it was running bunker first. The derailment, as in the other cases, took place at a curve where the radius of which, however, was moderate (22 chains). As in the other cases, the evidence as to speed was not satisfactory. The driver estimated it at 20 miles per hour, but Major Pringle thinks from the evidence this is not even approximately correct, and that the speed was much higher, and, after full consideration of all the available evidence, expresses the opinion that the derailment was mainly due to the train running with coupled wheels leading at a speed higher than is desirable for safety, and possibly higher than the superelevation on the curve justified.

BOILER ECONOMICS AND THE USE OF HIGH GAS SPEEDS.*

BY J. T. NICOLSON.

(*Continued from page 203.*)

PART IV.—HISTORY OF THE EXPERIMENTAL PLANT.

THE experiments here described upon the laws of heat transmission through the heating surfaces of steam generators were carried out with a Cornish boiler kindly placed at the author's disposal for the purpose by Messrs. Adamson and Co. This boiler was 6ft. 6in. mean inside diameter, and 24ft. long. It had one internal flue of Adamson ring construction 3ft. 5in. inside diameter. The fire-grate area, exclusive of deadplate, was 18·1 sq. ft. Several different dispositions of the various parts of the heating surface, both of the boiler itself and of the water tube surface outside, were made and tested.

The First Arrangement.—According to the first arrangement there was placed within the last 10ft. of the boiler flue an annular water drum which almost completely blocked it up, leaving only a narrow space 1in. wide for the passage of the products of combustion (see Fig. 11). Helical channels only ½in. wide for the circulation of water were arranged inside of this water drum; and through these channels water drawn from the boiler itself was forced by means of a small rotary pump, having a capacity of about 4,000 galls. per hour. The water entered at the front end of the drum from within and was forced to pass in close contact with the inner surface of the outer shell by means of a casting which projected forward so as to leave a very narrow opening all round the circumference. The water, or mixed water and steam, after flowing through the annular space, ½in. wide, between the two shells as a quadruple threaded helix of 38¼in. pitch, was discharged from the back end of the water drum by means of three outlets back into the boiler itself. The ordinary feed supply (from the tube economiser) also passed through this water drum, being mixed with the discharge from the rotary pump before entering the drum. The "economiser" consisted of 163 vertical tubes each of ⅞in. outside diameter, ⅝in. bore, 14ft. long, and 1⅛in. pitch, placed inside of a 16in. sheet steel pipe. Each tube had a ½in. square iron rod inserted within it and passing through its whole length (Fig. 12); very narrow channels were thus formed for the fresh feed to travel through, so that its speed of circulation might be sufficiently high even when the feed pump was running at a slow speed. In this first arrangement the feed entered at the top, flowed downwards into the bottom header, and so viâ the water drum into the boiler. The gases, after being drawn through the narrow flue round the water drum into a dust depositing box at the back, were led through the economiser in an upward direction within the 16in. pipe, which contained the 163 (⅞in.) tubes, and which formed a smoke flue leading to the fan. The fan, which was supplied by Messrs. Heenan & Froude, was 42in. diam. over the tips, and was capable of producing a vacuum of 16in. water gauge when running at 1,640 revs. per minute, and discharging 10,000 cub. ft. of air per minute at a temperature of 300° Fah. It was driven by a 50 b.h.p. electric motor furnished by the Electric Construction Company, Wolverhampton. Several runs were made with the plant thus arranged, the first being on July 13th, 1908. The results obtained on this date were as follows:—

Coal fired per hour (Ripley screenings), 1,200lbs.; being at the rate of 63lbs. per hour per square foot of grate.
Temperature of waste gases to fan, 340° Fah. to 400° Fah.
Temperature of entering feed, 80° Fah.
Temperature of top and bottom headers of economiser, 338° Fah.
Draught at fan suction, 21in. water gauge.
Draught at back of water drum, 8¼in. gauge.

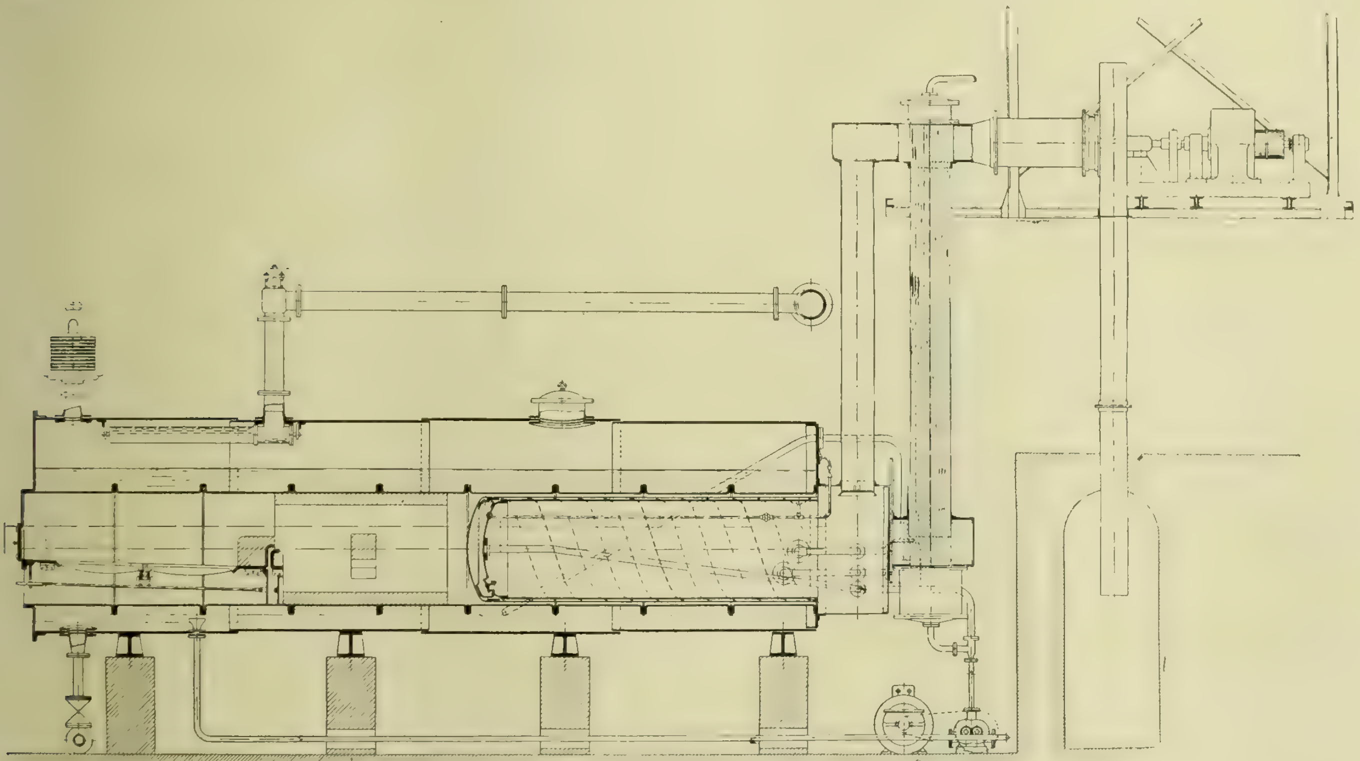


FIG. 11.—EXPERIMENTAL BOILER. FIRST ARRANGEMENT.

It had been hoped that the high speed of the combined feed and auxiliary water circulation in the spirals of the water drum would sweep along the steam formed therein and prevent it from accumulating in the upper part of the annular water drum. This hope was not realised, however, and a large amount of steam collected, more especially at the front end of the drum. The outer shell, consequently, got red hot, bulged, and leaked. It had also been expected that any steam that might be generated in the economiser tubes would, owing to the high speed of flow of the forced feed circulation, be carried down with the water into the lower header. So long as the feed pump was kept going at a good speed this appeared to take place; but at slow speeds of the pump the feed water remained stagnant in some of the feed pipes (instead of flowing steadily downwards in all); steam was generated in these, and rose into the top or entering feed header, and the proper operation of the counter current principle was interfered with,

* Paper read before the Institution of Engineers and Shipbuilders of Scotland.

Hence the temperature of the waste gases to the fan did not fall below that corresponding to the steam pressure (about 340° Fah.); and this inverted method of supplying the feed water, which had the advantage of delivering the gas to the fan suction by a very short duct (as the fan plant had to be suspended from the roof principals) had to be abandoned.

The Second Arrangement.—The economiser was therefore turned downside up, so that the feed entered at the bottom and any steam formed rose to the top. At the same time, new gas ducts were provided so that the furnace products entered at the top and left at the bottom of the economiser. The water drum was taken out, repaired, and replaced as before, but with a special steam escape pipe from the front top end of the water space (Fig. 11). This arrangement was tried on September 24th, 1908, with the following results:—

Coal fired per hour (Ripley screenings) 1,300lbs., equivalent to 68lbs. per square foot of grate per hour.

Temperature of gases in combustion chamber (dripping brick-work) (estimated) 2,600° Fah.

Temperature of gases leaving water drum flue (observed) 820° Fah.

Temperature of gases leaving economiser (observed) 170° Fah.

Temperature of feed entering economiser (observed) 71° Fah.

Temperature of feed leaving economiser (observed) 279° Fah.

Temperature corresponding to a boiler pressure of 60lbs. per square inch, 307° Fah.

Draught at fan suction	23½in.
Draught at bottom of economiser ...	23in.
Draught at top of economiser	7in.
Draught at back of water drum ...	6½in.

The remarkable rate of heat transmission from gas to water in way of the "water-drum flue" may here be pointed out. It was not then possible to measure the water actually evaporated; but the amount may be estimated within certain limits of error by the fall of temperature of the gases between furnace and economiser. Assuming a combustion chamber temperature of 3,000° Fah. (a result since confirmed by observation at similar rates of firing by Mr. Longridge), it is clear that each pound of the products of combustion of assumed thermal capacity 0·25 Th.U. gave up $0{\cdot}25 \times (3{,}000-832) = 542$ Th.U.'s whilst passing from the brick-lined combustion chamber to the dust-box. Taking only 14lbs. of air supplied per pound of coal $(1{,}300 \times 15) = 19{,}500$lbs. of gas flowed through the drum flue per hour; and gave up $19{,}500 \times 542 = 10{,}580{,}000$ Th.U.'s to the outer surface of the water drum and the inner surface of the furnace flue. The combined area of these two heating surfaces was 228 sq. ft. Thus the average heat transmission must have been of the order of $\frac{10{,}580{,}000}{228} = 46{,}400$ Th.U.'s per square foot per hour. This corresponds to an evaporation of about 48 standard units per square foot per hour— a result which is sufficiently surprising, but which has been to a large extent confirmed by Mr. Longridge's subsequent tests. It may be further pointed out that, owing to the proper carrying out of the counter-current principle, the waste gas temperature on this trial fell to 170° Fah., or just under 100° Fah. above that of the entering feed. Thus the results previously obtained from counterflow experiments with concentric pipes containing compressed air and water made with an apparatus provided for the author by Messrs Joseph Adamson & Co.* were confirmed, and it was proved that the extra steam necessary for driving the exhausting fan could be more than made up by the additional heat transferred to the water in an economiser of counterflow design.

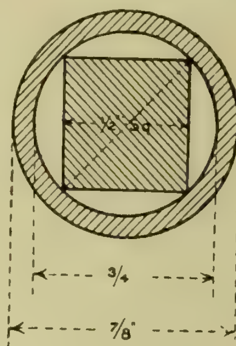


FIG. 12.

The steam escape pipe provided to permit of the discharge of the very large quantity of steam formed in the drum at its front end (Fig. 11) was not able, however, to prevent steam from accumulating therein. The drum consequently again got overheated, and had to be abandoned. The results were, notwithstanding, of so encouraging a character that it was felt that some further attempt should be made to make use of the enormous rates of heat transference which the high gas speed in the narrow flues had shown to be possible.

* Trans. The Junior Institution of Engineers, Vol. XIX., February, 1909.

The Third Arrangement.—It was accordingly determined to remove the water drum from the boiler flue, and substitute for it a brick plug 38in. in diam. and 10ft. long, leaving a space of 1½in. all round between it and the (41in.) flue (Fig. 13). As the gas temperature was not expected to fall below 1,400° Fah. with this arrangement, it was further decided to fit a vertical small tube "evaporator" between the back of the plug and the top of the economiser. This evaporator was of the same design as the economiser, except that it consisted only of 90 tubes each of ⅝in. outside diameter, ⅜in. bore, and 12ft. long; the central portion of the 16in. containing pipe being filled up with a 6in. pipe to which the gas had no access. It was arranged that the feed upon leaving the economiser should go either directly into the boiler, or go there after mixing with the circulating water drawn by a rotary pump from the boiler and forced through the 90 tubes, of ⅜in. bore, of the evaporator, and again into the boiler, so as to accelerate the circulation in the same. The arrangement is shown in Fig. 13. The re-arranged plant was first tried on January 8th, 1909, and the following results obtained:—

Coal fired 840lbs. per hour (Ripley screenings) or at the rate of 44·2lbs. per square foot of grate per hour.

Temperature of gases in combustion chamber 3,000° Fah. (estimated).

Temperature of gases leaving brick plug 1,200° Fah. (observed).

Temperature of gases leaving evaporator 620° Fah. (observed).

Temperature of gases leaving economiser 140° Fah. (observed).

Temperature of feed entering economiser 70° Fah. (observed).

Temperature of feed leaving economiser 270° to 340° Fah. (observed).

Temperature corresponding to boiler pressure of 120lbs. per square inch 340° Fah. (observed).

It will be observed that the waste gas temperature fell in this experiment to within 70° Fah. of that of the entering feed. Compared with a boiler plant, in which the waste gases reach the chimney at 540° Fah., this corresponds to an increased evaporation of about 1½lbs. (standard) per pound of coal. The transmission through the heating surface in way of the plug flue was in this instance $840 \times 15 \times 0{\cdot}25\ (3{,}000-1{,}200) = 12{,}600 \times 45 = 5{,}670{,}000$ Th.U.'s per hour; or at the rate of $\frac{5{,}670{,}000}{118} = 48{,}000$ Th.U.'s per hour per square foot of heating surface. Such a rate of heat transmission had never before been recorded for the heating surface of a steam boiler not exposed to direct radiation from the furnace itself. The rate of heat transmission in the economiser can similarly be estimated. Here the mean temperature difference between gas and water was much less than in the plug flue, being about 200° Fah. only, instead of 1,600° Fah. The heat transmitted was about $12{,}600 \times {\cdot}24\ (620-140) = 12{,}600 \times 115 = 14{,}500{,}000$ Th.U.'s per hour. The heating surface being 521 square feet, the rate per square foot of tube surface was $\frac{1{,}450{,}000}{521} = 2{,}785$ Th.U.'s per hour.

This is as much as some boilers give as an average for the whole (excluding economiser) of their heating surface. The effect of gas speed in promoting rapidity of heat transference was in this way definitely shown; and there seemed to be a possibility by its use of greatly reducing the ratio of heating to grate surface below the usual value, without at the same time causing the diminution of efficiency which has always hitherto been associated with forced rates of combustion and evaporation in steam boilers of every type. It was accordingly decided to keep the boiler under steam for several months, and to make observations of the various temperatures both of the gases and feed water, and of the draught vacua at several points in the flues. It was also desirable to weigh the coal

and measure the feed, and for this purpose tanks and a weigh scale were, after a white, made available.

Some little trouble was at first experienced with the fan plant. The motor being only semi-enclosed and placed in a very dusty place, it was thought advisable to enclose it wholly within a housing of wood and glass. In order to keep the armature cool, a fresh-air duct from outside the boiler-house was then led into the housing, and a suction pipe was led out from the other end to the centre of the fan casing. This arrangement was found to be quite inadequate, even at light loads, notwithstanding that the draught pipe to the fan centre was successively increased from 2in. to 4in. in diam. A small propeller fan was then designed and fixed upon the end of the motor shaft, so as to blow air over the commutator and through between the armature and the pole faces, whilst a wooden diaphragm placed across the housing prevented the air from going round outside the magnets. A door in the housing on the side of this diaphragm remote from the fan being then left open, the warm air was simply discharged direct into the boiler-room. These measures proved perfectly successful, and no further trouble was experienced from the overheating of the motor.

The next difficulty encountered was from the powerful end thrust produced upon the fan and motor shaft by the one-sided entrance of the exhausting gases under a vacuum of from 15in. to 20in. of water. The neck-journal next the fan casing gradually wore away the metal of the bearing, reached the white metal, and melted it. After several attempts to run with thrust collars which it was found impossible to keep cool, a double ball thrust-bearing supplied by the Hoffmann Manufacturing Company was fitted, and was found to answer admirably. The fan plant subsequently gave no further trouble as to its mechanical working, and its operation in producing the required vacuum and in removing the waste gases (whose temperature never rose above 290° Fah.) was all that could be desired. The principal object in continuously running this experimental plant was, of course, to ascertain on the one hand whether the narrow gas flues would become blocked up with coal dust on the outside; and, on the other, to observe what would become of the sediment and gases contained in the feed when set free in the narrow water channels of the economiser and evaporator.

The Gas Flues.—The long economiser tubes of $\frac{7}{8}$in. diam. and pitched $1\frac{1}{8}$in. from centre to centre, had been somewhat improperly handled, both by unequal expansion when first used in the inverted position and (probably) when being taken out, turned end for end, and replaced before the trial of September 24th, 1908. In some places they were too widely spaced, and in others they were standing packed together in groups. The natural consequence was that coal dust and soot began to bridge across from tube to tube, and a vacuum of even 27in. of water produced by the fan was latterly found to be insufficient to burn the required quantity of coal. It was therefore decided to re-tube the economiser with about two-thirds of its former number of tubes, at a wider pitch, and with an iron pipe 6in. diam. forming a central core to restrict the area of the gas passage. With such more widely-pitched tubes of the same total length (the old tubes were reinserted) so low a waste gas temperature as 140° Fah. could no longer be expected; but calculation foretold that it might be expected to fall to about 220° Fah. On March 22nd, 1909, this re-tubing was completed, and on that date a trial under the new conditions was made.

It was satisfactory to find that the waste gases were reduced to 190° Fah., notwithstanding the wider pitching of the tubes. This unexpectedly low gas-outlet temperature was, however, only maintained whilst the tubes were perfectly clean. It was found that, after a few days, a thin coating of coal dust had adhered to the tubes, and the average value of the outlet temperature had risen to 240° Fah.

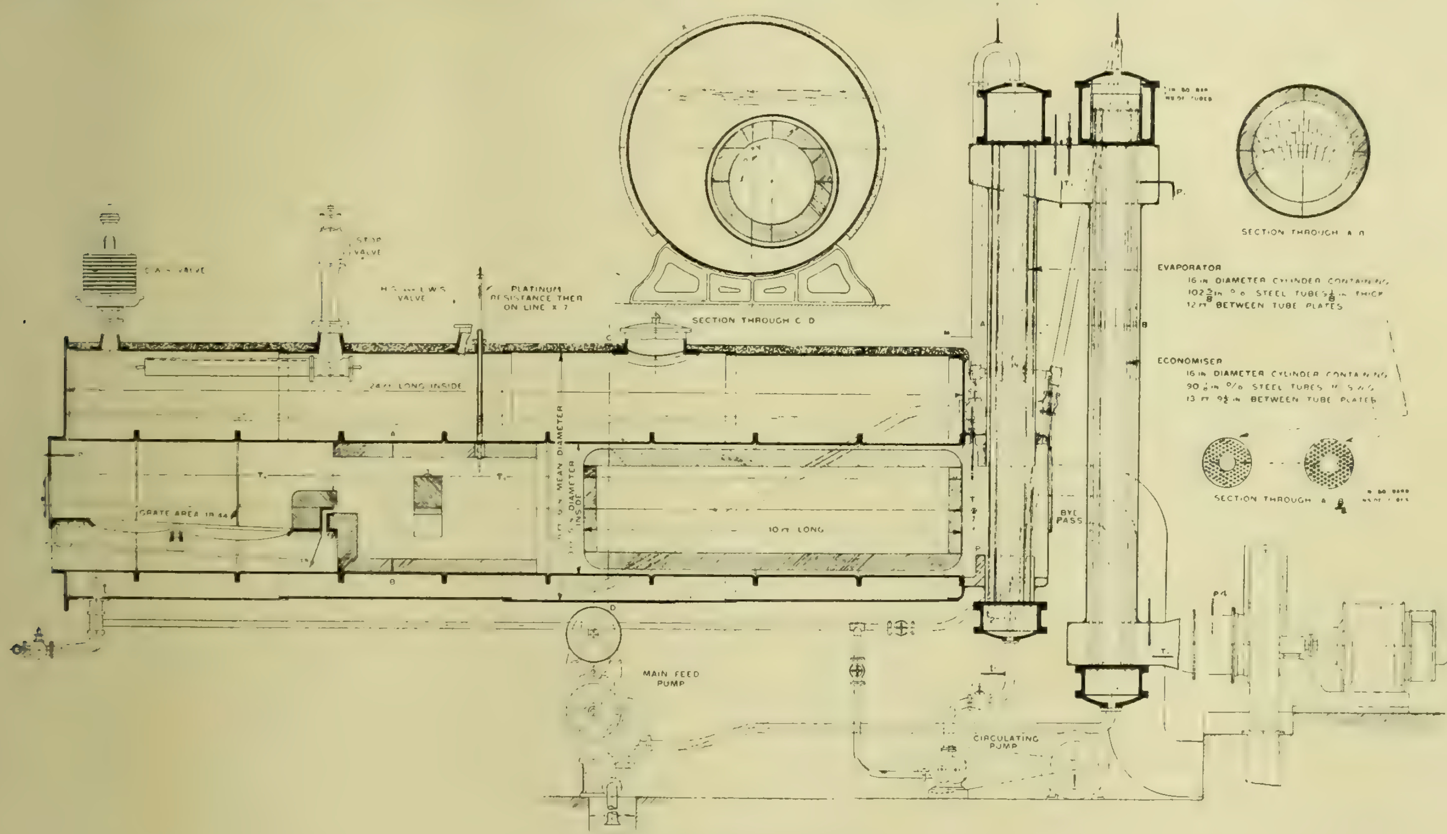


FIG. 13.—EXPERIMENTAL BOILER.

On the trials made six months afterwards, in October, 1909, by Mr. Longridge, after 50 days of running of the plant at draughts of from 15in. to 20in., the waste gas temperatures were, however, found to be of substantially the same value, depending only on the rate of firing, *i.e.*, on the initial temperature of the products of combustion when leaving the combustion chamber to enter the narrow flues. Thus the soot film was found to have attained, as a permanent regime, under the scouring action of the gases, a thickness sufficient to prevent all corrosion of the tubes, but not sufficient to prevent the gases from transferring their heat to the metal at a much greater rate than that commonly found in steam boilers.

The Water Channels.—It was also gratifying to find that in the very narrow water spaces of the economiser (viz., those left by a $\frac{1}{4}$in. square rod placed inside of a $\frac{3}{8}$in. bore-pipe) (Fig. 12), there was no deposit either upon the rods or the tubes. There was also practically no corrosion, although Mr.

Longridge found "slight but unmistakable pitting by oxygen" on the upper ends of the rods when he examined the economiser in October, 1909. This pitting was, however, in the author's opinion, probably due to the water standing in the tubes at nights when the fire was banked and the feed pump shut off. The upper parts of the evaporator tubes (of $\frac{5}{8}$in. outside diam. and $\frac{3}{8}$in. bore) above the level of the boiler water were also free of sediment, notwithstanding the fact that the dirty water from the economiser had been passed through the evaporator on its way to the boiler during the whole 50 or 60 days the plant had been at work. Below the boiler water level, however, the evaporator tubes had become gradually blocked up inside with a white sediment which was very hard and adherent for the first foot or two from the bottom, but soft enough to be pushed out by a $\frac{1}{4}$in. rod between that and the water level. In order to understand how this occurred the arrangement of the plant must be looked at, as shown in Fig. 13.

When the evaporator was fitted (in order to provide the additional surface necessitated by the removal of the "water drum") it was, in order to save expense, simply passed through the old "ash box" in way of the old by-pass; that pipe being, in fact, itself made use of as part of the containing pipe for the new evaporator. The new tubes passed vertically completely through the "ash box," and took their water supply from a water-header placed below the same. It resulted from this that during the night, when no current was available to drive the circulating pump, and the feed donkey was also shut down, there was no circulation whatever through the evaporator tubes except that due to the gravity displacement by the boiler water of so much of the water in the tubes as was turned into steam and passed away into the boiler steam space. From 700lbs. to 1,000lbs. of coal were burnt during the 15 hours of banked firing which took place on each of the 50 or 60 days the plant worked, and the only way by which the gases so produced could get to the chimney was by flowing around and amongst the lower ends of the evaporator tubes on its way to the by-pass duct. The result was the choking with sediment up to the level of the boiler water, described above. No doubt such a result ought to have been foreseen and provided against. To the author's mind, however, a lesson was conveyed in a very striking fashion of the necessity for rapid and positive movement in a boiler circulation in order to prevent the deposition and adherence of sedimentary matter wherever the surfaces are exposed to the contact of heated gases. The extent to which this choking of the tubes in their lower parts had proceeded was not realised until shortly before the official trials by Mr. Longridge were to take place.

The circulating pump, which drew from the boiler and passed water upwards through the evaporator tubes (along with the fresh feed from the economiser) began (in September, 1909) to take so much current through the armature of its motor that it was constantly stopping owing to the fuse blowing; and when the plant was opened to find the cause of this great hydraulic resistance, it was found, as already mentioned, that quite a number of the tubes were completely choked, that many of them had only a fine hole through their centres, so that, whilst enough remained clear to allow of the feed pump passing the relatively small quantity of fresh feed into the boiler through the evaporator without difficulty, the rotary pump was opposed by a greatly restricted area for the flow of its 4,000 gallons an hour. The author at once reported this state of things to Mr. Longridge, and invited him to make an inspection of the plant, so that he might satisfy himself that the cause of the choking had been the boiling of the water in the pipes during the night when no positive circulation was possible. This inspection took place on September 22nd, 1909. Over-heating and bending of a few of the evaporator tubes was then found, in the case of those tubes only which had been completely choked with sediment and which had been exposed for some days, or even weeks, to the contact not only of the moderately hot gases at nights, but also of the products at 1,200° Fah. to 1,500° Fah. which had passed over them at high speed during the day time. Notwithstanding this ill-usage, not a single tube gave way, nor was there any sign of leakage at the tube plates. These tubes were 12ft. long and $\frac{5}{8}$in. diam., and being of only $\frac{3}{8}$in. bore, were $\frac{1}{8}$in. thick.

The results of this experiment seem to point to the feasibility of using small bore tubes with thick walls to withstand the fierce heating action of high-speed gas at high temperatures when a positive circulation at moderate velocity is available. The plant was laid off for a week or two before the trials in order to allow of the removal of as much as possible of the hard scale from the lower ends of the evaporator tubes. No cleaning of any part of the sooty outside surfaces of the tubes of the economiser or evaporator was attempted, or was, indeed, possible. So far as could be seen there was but little adherent matter on the inside of the furnace flue in way of the brick plug; but whatever there might be was not scraped off, as it was not believed to be seriously prejudicial to heat transmission. The plant went, therefore, into Mr. Longridge's hands for testing just as it was after 51 days of steaming; and although the results obtained on the trials and reported by Mr. Longridge, with regard to the rate of heat transmission, may be considered to be high, there seems no doubt but that in a plant so designed and constructed as to admit of its being cleaned at intervals, a still higher evaporative power would be attained.

(*To be continued.*)

THE INTERNAL-COMBUSTION ENGINE AND ITS USE ON LOCOMOTIVES.*

BY W. R. MCKEEN, JUN.

THE internal-combustion engine is ordinarily considered a late invention and yet it seems to be older in principle than the steam engine. We have a record of an internal-combustion engine using gunpowder as a fuel, as far back as 1678. In the 80's the internal-combustion engine was developing rapidly and its practical use was recognised. Useful practical development in the gasoline engine dates not much over 20 years. A great many mechanical devices are to-day made possible and practical by the internal-combustion engine and by this form of engine alone. Its remarkable efficiency, its remarkable proportion of horse-power developed per pound of weight, its reliability of performance, make it a prime mover, when rightly appreciated, far superior to any other form of power-generating apparatus. One of its chief characteristics is its reliability of performance and simplicity.

Even a casual consideration of the usefulness of the internal-combustion engine to-day is really startling. In 1912 the French army equipment comprises 325 aeroplanes, and it is expected to have this number increased to 800 in 1913—navigation of the air made possible by the internal-combustion engine. A large internal-combustion-engine-propelled sea-going battle-ship, smokeless, stackless, coalless, almost submerged, to outclass the most modern Dreadnoughts, is being built. It is only in 1905 that a gasoline-propelled 600 h.p. torpedo boat, built in America, was the first internal-combustion-engine-propelled craft to cross the Atlantic. The internal-combustion engine in automobile service has demonstrated its supremacy over all other kinds of power, and in this business the highest developed steam engine machinery known to man has given way to the internal-combustion engine.

When one reflects upon the careful thought given to the steam engine for a century and more and thinks of the close attention that is given to the care of the steam engine to-day, and then compares this to the lack of intelligent supervision given to internal-combustion engines, considering the days, months, and years that internal-combustion engines sometimes run, without any expert inspection or any attention whatever, noting the wonderful performance day in and day out of the internal-combustion engine of automobiles, handled by women and men of all walks of life and the cars attended to by men that scarcely know the difference between gasoline and coal oil; the comparison alone is conclusive as to the future of the internal-combustion engine. The introduction of internal-combustion engines into general use has been so rapid that they necessarily have had to be handled and looked after by people not familiar with machinery and not familiar with their working. Men experienced in handling internal-combustion engines could not be developed fast enough to look after the product, notwithstanding that information in handling the

* Abstract of address delivered before the committee of investigation on smoke abatement and electrification of railway terminals, Chicago, May 31st, 1912.

internal-combustion engine has probably spread more rapidly than information on any other kind of power.

A well-developed design of electric motor under many conditions gives good service day in and day out without any great amount of trouble, and yet there are danger lines—a little undue moisture, a little undue heat, a little neglect of the proper lubricant to the armature shaft, and the whole apparatus is out of commission and repairs made very complicated; but the internal-combustion engine stands all kinds of abuse and yet will keep running. I have seen internal-combustion engines give regular service every day, making many miles under conditions that really to all human comprehension would have seemed impossible. I have in my personal experience observed gasoline engines running for a year at a time without ever opening the crank case; without ever making an opening to the cylinder; and without ever making an adjustment on the prime mover as a mechanism itself, and these same engines at the expiration of a year were in good condition. The only human attention they had received whatsoever was the furnishing of the supply of gasoline for the carburetter and oil for the lubricator.

In electric traction equipment the electric motor runs normally at a very high speed, and a reduction of this speed in the transmission of power to the driving wheels is done through gears. This gear transmission alone entails a loss of from 12 to 20 per cent. of the power developed by the motor. These gears wear very rapidly and are noisy. While they are reasonably efficient when the gear teeth are of the proper shape and new, as soon as they wear the loss in efficiency increases rapidly.

The steam locomotive transmits its power to the driving wheels from the cylinders through a system of guides, crossheads, and rods. This is a well developed transmission and the parts are well worked out from long experience and yet there is more or less breakage. The transmission requires constant inspection and attention. In ordinary freight service the power used to drive the locomotive and tender and to overcome the friction of the mechanism is from 15 to 35 per cent. of the total power developed in steam cylinders. The internal friction alone of a locomotive varies from 12 to 20 per cent. —indeed, it is safe to say with an ordinary freight engine, partially worn, most of the time it will run much over 20 per cent. The counter-balance of the large modern type locomotive becomes a very severe tax on the track and road bed, particularly at high speeds.

The application of steam and electric power to transportation mediums has been well established; the application of the internal-combustion engine to railroad mediums is in its infancy, but when the possible economy with the internal-combustion engine is considered, the future extensive use of this form of power is readily appreciated. For a single unit or car proposition we have the prime mover, the internal-combustion engine, the power being transmitted to the driving wheels by a chain. Using the frictionless chain, the chain pins are knife edges working on each other. The power from the generator can be transformed from the crank shaft to the periphery of the driving wheels with a loss of 3 to 4 per cent. when direct connected. The only complication in the use of this power is in its original application to the load. But with a friction clutch interposed between the prime mover and the driving wheels, which is a simple proposition, and a gear, for temporary purposes, easily thrown in and out, the problem is solved.

Logically, in the face of the economy necessary in transportation business of the present day, the use of the internal-combustion engine in transportation service is a necessity. Consider a steam switching locomotive. A large part of the time it is merely consuming fuel, water, &c., at a rather high rate—waiting for work to be done; the fire must be kept up long before the working hours in the morning until long after working hours are over in the evening—in fact it is economical to keep the fire going 24 hours each day. Now compare it with the internal-combustion-engine-propelled locomotive in which the consumption of fuel stops immediately the engine is stopped. The steam switch engine ordinarily is used in shifting cars, and for the most part the reverse lever is in the corner—full stroke—no use whatever being made of the expansive possibilities of steam. The steam is generated in a boiler at a certain pressure, a certain quantity of high-pressure steam is transmitted to the cylinders, and the cubic contents of the cylinders are simply a measure of the number of cubic inches taken from the boiler. This is an excessively wasteful method of generating power, and yet this is the condition under which the switch engine normally works.

With a reasonably flexible transmission from an internal-combustion engine, the engine can be worked at an economically advantageous speed under almost all conditions; so that the necessary appliances—in order to obtain the flexibility to transmit and apply the power from an internal-combustion engine to the driving wheels of a transportation medium—are economical and advantageous devices; they are a necessity in the application of the internal-combustion engine and yet in their action the internal-combustion engine is enabled to operate at all times on an economical basis.

The use of friction clutches for mining and hoisting engines, and for large bending rolls, is old and the results obtained have been extremely satisfactory and reliable. The use of the friction clutch on a transportation medium is therefore really of no great importance in the solution of the subject matter at hand.

There are already developed several oil transmissions for the transfer of power. These oil transmissions have a wonderful range of flexibility, susceptible of positive and easy control. The gasoline engine as a prime mover, therefore, with an oil transmission between it and the driving wheels of a switch engine, would give a locomotive under the control of the operator, of far more scope in its operation than a steam locomotive ever could be. It should not be difficult to connect driving wheels by this form of transmission to an internal-combustion engine.

A small 200 h.p. or 300 h.p. engine with this form of transmission could be designed to give more tractive effort than a 700 h.p. or 800 h.p. steam locomotive for starting purposes. The speed of a switch engine, controlled by this hydraulic oil transmission, would vary from zero to 20 and 25 miles an hour, giving an infinite number of speeds. A 200 h.p. gasoline engine would start a 30 to 40 car train as positively as a 500 h.p. locomotive, the only difference would be in the acceleration. It is reasonable to suppose that the 500 h.p. steam locomotive would accelerate the load faster than a 200 h.p. internal-combustion engine locomotive. On the other hand, the economies of transmission, the efficiency, the application of the power, the facility of manipulation with the internal-combustion engine being so far superior to that of a steam locomotive, there is no question that a rated horse-power internal-combustion engine would more than compete with the steam engine of very much higher rated horse-power in every-day service. Take a locomotive with cylinders 20in. by 24in., drivers 51in. diam., boiler pressure 180lbs., at three miles an hour; the horse-power developed by this steam engine is only 249, notwithstanding the fact that the engine is capable of developing 600 h.p. or 700 h.p.

Denatured alcohol should be made at a small cost, and could be used as a fuel readily and easily interchanged in use with gasoline in the ordinary apparatus. The application of heat to carburetting devices will easily enable the utilisation of coal oil or even crude oil for switch engine purposes. The utilisation of different kinds of coal, even lignites, by means of gas producers for fuel, furnishes an endless source of economy and development for the future of the internal-combustion engine in its general use. With reasonable study and development work there are a great many economies possible in the use of gasoline. It is simply a question of time when these will be obtained. Thus it is that the internal-combustion-propelled-transmission medium's field for further economies and greater adaptability is enormous and not particularly difficult, whereas any great economies in the use of the steam locomotive are practically restricted to a very narrow margin, and as a fact possible economies in steam power available to-day seem to be of such minor importance as not to justify their use by the railroads at large.

Fuel for the internal-combustion engine properly mixed with air and economically utilised in the cylinders will give off practically no smoke, no disagreeable odours. The internal-combustion engine to-day affords us more efficient, more adaptable, and more practical form of transportation medium than the steam engine, whether it be for slow, fast, or heavy service; there is practically no smoke, practically no noise, and it has none of the dangers, nor any of the complicated restrictions incident to a third-rail electric system. Its practical introduction is simply the combining of the already-mentioned parts in a composite design and the adapting of them to the certain specified duty required.

NEW DEVELOPMENTS IN STEAM TURBINE ENGINEERING.*

BY EDWIN D. DREYFUS.

THE first milestone of turbine progress was reached when Parsons introduced his unique turbine in 1884, which time witnessed the transition of the steam turbine from the realm of virtual mysticism—as these motors in their primitive form probably impressed the people of the earlier days—into apparatus of commercial utility. Its advance was naturally slow during the earlier period of development, but it gained notable headway in the ten or 15 years following its introduction. The most prominent factor in preventing a more

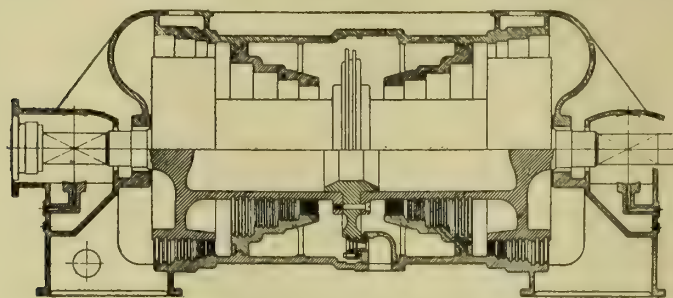


FIG. 1.—DRUM-TYPE TURBINE—LARGE SIZE.

general use of the turbine was the lack of machinery which could utilise, in a practical way, the power developed. The turbine being inherently high speed, made the provision of a driven machine of corresponding speed necessary, or else connection through reducing gears, and inasmuch as these were not available in the infancy of the industry, turbine progress has therefore in the past been more or less closely related with the complimentary electrical equipment, chiefly of the alternating current type.

The first generator which was driven by a turbine was of the historic bipolar "Jumbo" design, operating at a normal speed of 18,000 revs. per minute and developing a maximum output of 6 e.h.p. From this modest beginning the turbine was energetically pushed, and by 1889 turbine units aggregating 5,000 kw. were installed and operated, and in 1894 the 10,000 kw. mark had been reached. This period not only witnessed the initial application of the turbine to marine work, but also marked a beginning of the broad highway of turbine progress leading down to the present day, which claims an aggregate turbine capacity of 25,000,000 h.p. in actual service.

The developments have been so far-reaching during the past few years that many new milestones have been rapidly passed. Thus, for instance, the range of turbine capacities has been extended from 1 to 20,000 kw. and above; the low-pressure turbine, the automatic bleeder turbine, the improved non-condensing turbine have been accorded wide application in central station work. In auxiliary service such as excitation, boiler feeding, and condensing equipment, the small turbine is filling a long-felt need. The practical development of the reduction gear for high powers has brought the turbine into the high-duty water pumping field, and has provided for the application of large high-speed turbines to direct current generation, and likewise to non-reversing rolling-mill drive.

Thus it may be properly said that the turbine has invaded practically every class of power application, with the possible exception of those cases requiring reversing operation, as in hoisting and blooming mill-work. As a review of turbine development it may prove interesting to reproduce the following tabulation:—

† TABLE I.—*Performance of Parsons Turbo-Generators at different epochs.*

Date.	Power kw.	Steam per kw. hour.	Vacuum 30in. Bar.	Suplit. Deg. Fah.	Steam Pres. lb. per sq. in.
1885 ...	4	200	0	0	60
1888 ...	75	50	0	0	100
1892 ...	100	27	27	50	100
1900 ...	1,250	18·22	28·4	125	130
1902 ...	3,000	14·74	27	235	138
1907-10 .	5,000	13·2	28·8	120	200

* Paper presented before the Western Society of Engineers, March 4th, 1912.
† From A. Richardson, "The Evolution of the Parsons Steam Turbine."

Hence it will be seen that the turbine came up to the best reciprocating engine performance in a comparatively short time, and to-day excels in all important sizes.

Ranges in Commercial Sizes.—Probably one of the most notable features of turbine progress has been the remarkably short space of time in which its design has become feasible for both very small and very large powers. A few years ago the concentration of 50,000 h.p. in a single machine was not seriously thought of even by those who are customarily accredited as visionary. Although at the present moment we have no turbine which has as yet reached these stupendous proportions, we are, however, to-day observing the building of units of 30,000 h.p., and the next step to the large size named is now readily surmountable. One may fully grasp the significance of this advance when it is considered that a 30,000 h.p. unit will displace four of the largest reciprocating engines built, and, moreover, occupy about 25 per cent. of the space and volume. It is at once apparent that there is a large measure of economy realised both in investment and running expense. With increasing size of turbines there is a continual improvement in economy, all conditions being favourable. The most important factor in large turbines, then, is the question of mechanical design. There can be no doubt that a rigorous demand is made of the designer that the essential details be executed with every regard for operating loads and stresses. Several different types of large turbines are being brought to the fore, but the pre-eminent fitness of any will be properly gauged, of course, by their relative immunity from troubles of any moment. The drum-type turbine has much to recommend it, particularly for large powered units. A detail section of a turbine of this construction is presented in Fig. 1, and which as proportioned is capable of developing 20,000 kw. or 30,000 h.p. This represents the double flow type, combining the impulse and reaction principles, and through the division of steam between the right and left hand elements, higher rotative speeds have been made possible with the reduction in diameter of the low-pressure rings. As a result, substantial betterment in construction, and a decrease in weight and dimensions, have been effected, ensuring greater homogeneity of the entire structure. It will be noted that the unit is constituted entirely of drum and blade rings. Discs are not employed. Operating at 1,500 revs. per minute may appear somewhat startling at first when some of the early designs of turbines adopted speeds of 750 revs. per minute for units of only 2,000 kw. capacity. Strange as it may seem, the disc con-

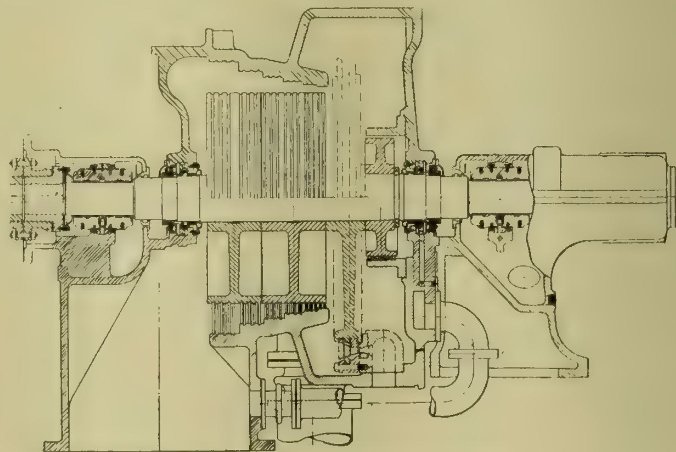


FIG. 2.—CONVERTIBLE-TYPE TURBINE.

struction, although it is capable of being worked at higher stresses than the drum type, the latter may be constructed with greater facility to comply with requirements of good steam economy and still possess the greater factor of safety. The steam consumption with moderate working condition (175lbs. gauge pres. 100° supt. and 28in. vac.) would at full load amount to 13·5lbs. per kw. hr. When the very small turbines are considered, the problem is of a different order in obtaining maximum simplicity with reasonable efficiency.

Between such limits the variation in design is quite marked. Single disc wheel construction is retained until capacities of 300 kw. are reached. At this point, the steam volume

becomes sufficient for using reaction blading of economical proportions. There is manifestly a definite relation of the leakage annulus or area over the tips of the blades to the blade lengths which prohibit their use commercially in smaller sizes. On the other hand, the percentage leakage loss greatly diminishes with increase of size, and the economy is correspondingly improved.

Consequently there exists a large variation in construction, depending upon both working conditions and capacities involved, and the designs therefore take either the form of a simple impulse wheel, or the straight Parsons construction, or else some effective combination of the two. For moderate sizes, somewhat above and below 1,000 kw. capacity, the straight Parsons type works out most advantageously in regard to economy and mechanical design. In larger sizes there is much gained from a structural standpoint by means of the combined type, although the efficiency is not noticeably affected. The condition is practically the reverse in small units, where the construction requirements cease to be a factor, while the efficiency may be improved by replacement of very short blades in the high-pressure section of a Parsons turbine by an impulse wheel. As the character of the work varies, different arrangements may be adopted, and these facts simply serve to illustrate that the turbine is no longer circumscribed by narrow limits, but admits of wide flexibility in its application Many of the features here described will be observed in the accompanying detail views of turbines built for various purposes.

Special Service.—Under this classification, the implication is that special regard must be paid to the proportioning of the turbine with reference to the nature of the steam supply as well as its speed and the output developed. It is here considered that the complete expansion of the steam from boiler pressure to the absolute vacuum maintained represents ordinary practice, and would therefore only require the regular designs already referred to. But there are sets of conditions which call for special designs, briefly enumerated below, and which typify some of the more prominent of recent developments in the steam turbine art.

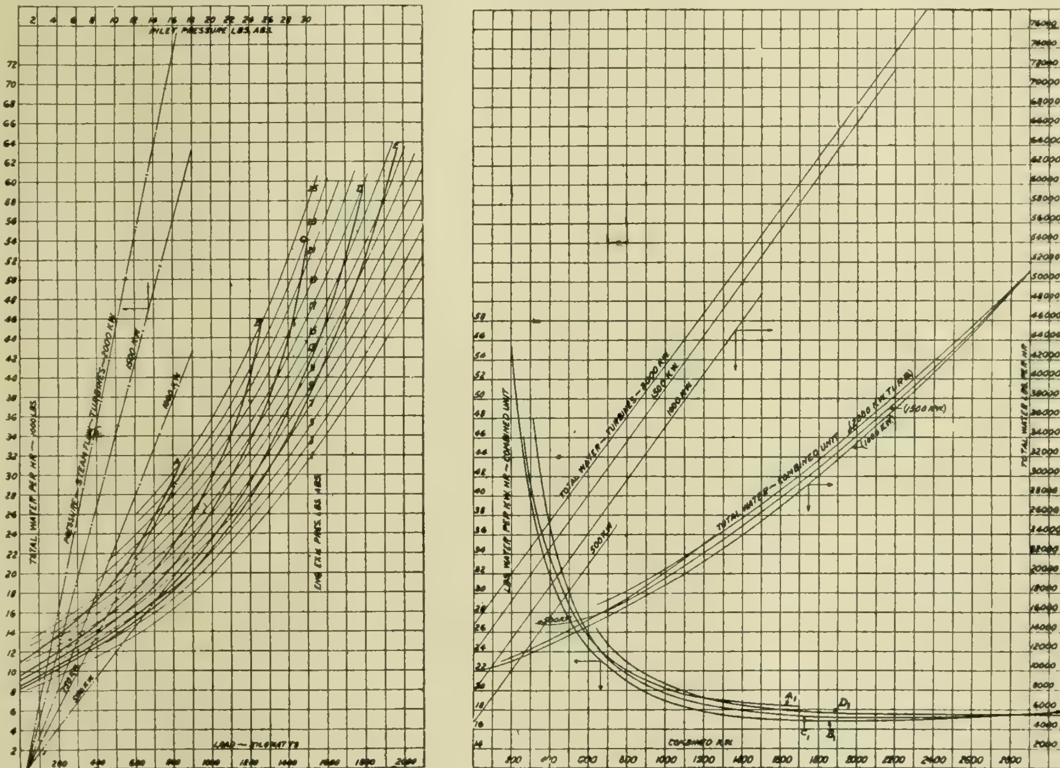


Fig. 3.—Curves Showing Steam Economy.

(1) Utilising low steam pressures, atmospheric or less.*

(2) Operated strictly non-condensing, with or without back pressure.*

(3) Diverting part of the steam from the turbine for heating purposes, termed bleeding operation.

Low-pressure turbines have now become so well known that little mention of their advantages need be made here. It is possibly well, however, to reiterate the salient point that they profitably utilise the lowest practical exhaust pressures, where the reciprocating engine would receive no benefit, direct or indirect. One of the most convincing demonstrations of this quality of the turbine is the larger number of stations which formerly operated non-condensing piston engines on account of inadequate cooling water supply, which are being converted into condensing plants through the addition of low-pressure turbines and cooling towers. The engines alone would not have justified the cooling-tower investment. Improvement is not only to be found in the existing non-condensing systems, but power plants formerly consisting of the most modern type of compound condensing reciprocators have been able to realise a large betterment in economy by supplementing the engines with low-pressure turbines. A concrete example will forcibly attest the economic results attained. An electric railway power station originally contained five 1,000 kw. Corliss compound condensing engines. A low-pressure turbine of 2,500 kw. capacity was later installed. Concisely the improvement obtaining is:—(1) Plant capacity increased 50 per cent.; additional boilers unnecessary. (2) Reduction in station operating force 15 per cent. (3) Fuel saving 22 per cent. The fuel is of 11,000 B.T.U. value, cost 7s. 6d. per ton delivered, and is equivalent to a return of 48 per cent. on the investment, or, in other words, the new installation would pay for itself in two years' time.

Besides these items there is economy effected in oil, supplies, and repairs. Moreover, this addition was made at (roughly) one-half the cost that would have been necessary to install duplicate engines. A type of low-pressure turbine which is extensively used, also embodies the double flow construction, and is quite similar to Fig. 1, with the high-pressure part, however, removed. That part of low-pressure turbine engineering which attracts the greatest attention is the variety of the systems of governing which have been developed to satisfactorily secure elasticity and efficiency over a wide range. These may be divided into, approximately, six classes, as follows:

(1) Without governor—electrically controlled through synchronising force of generators.

(2) Governor control with auxiliary live steam admission.

(3) Electrical tie between turbine and belt engines through synchronous motor.

(4) Automatic by-passing of surplus low-pressure steam to condenser.

(5) Use of a reserve high-pressure element.

(6) Heat regenerators, accumulators, and storage systems.

While heretofore the development of the low-pressure turbine has mainly centred about the governing mechanism, an important innovation in the mechanical design has been made in the construction of a convertible type as shown in Fig. 2. This is a single flow reaction element with provision for the introduction of a high-pressure impulse wheel when operating conditions may demand it. Such a type would prove of great value in the case of abundant exhaust steam being available at first, but afterwards seriously reduced by other changes about the plant, full advantages of the low-pressure feature may be thereby lost. By locating a high-pressure wheel as shown, the turbine may be economically

* Curiously, the first steam engine operated altogether on low-pressure steam (atmospheric condenser pressure), but evidently this was due to the state of the mechanical art at that time, and necessarily involved special conditions.

operated either as a mixed pressure or independent high-pressure unit.

Much has already been said of the facility with which low-pressure turbines may be adapted to widely different requirements. There is another feature in combining it with a given engine, worthy of special comment: viz., that of the low-pressure turbine to be selected being not necessarily confined to a fixed capacity. But, on the other hand, there is considerable latitude practicable in the selection of the low-pressure turbine, thus making possible different overload capacities and light load economies without greatly affecting the efficiency of the combined unit at rated output. With

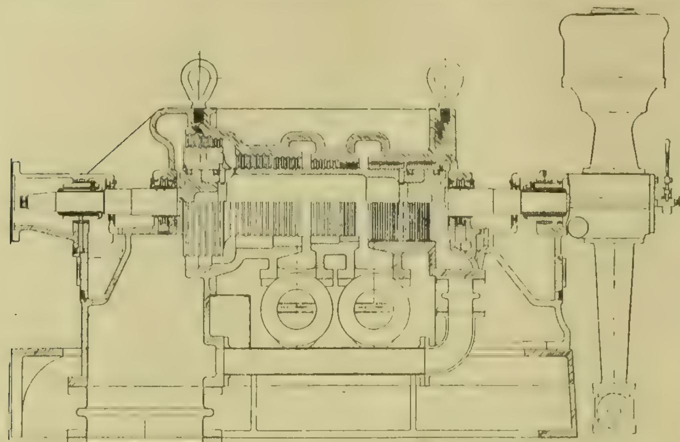


FIG. 4.—NON-CONDENSING TURBINE.

these advantages, the size of low-pressure turbine would then be influenced either entirely by present conditions or by future requirements as regards the combined normal capacity.

The points to be considered centre primarily about the selection of the intermediate pressure between the engine and the turbine to carry normal capacity of the turbine. Obviously the higher this pressure is set, the smaller the low-pressure turbine frame for a given capacity. On the other hand, the lower the pressure taken for normal conditions, the larger the low-pressure turbine frame must be. Evidently in the first case of a high intermediate pressure, the output from the engine becomes materially reduced and maximum overloads which may be carried are likewise affected. This fact may be best appreciated from Fig. 3, showing the total water characteristic of the high-pressure engine when operated in connection with turbines of different sizes. As the back pressure on the engine is lowered, the turbine size must increase, which, in addition to extending the point of maximum economy of the engine, also raises the capacity of the combined unit. The range in operating load should also be considered, since, where larger turbines are operated at light loads, the economy may be inferior to that shown by the unit having the smaller low-pressure turbines. This is due to the fact that light-load losses, for fractional-load operation of the combined unit, are greater for the larger than for the smaller turbine.

By working out a definite case it has been found that where the turbine size is increased as above, the gain in the engine due to lowering the back pressure slightly exceeds the loss in the turbine element following upon a decreased inlet pressure and fractional-load operation. This is evident from Fig. 3, showing results that have been deliberately worked up for a 28in. and 54in. by 48in. engine, operating with low-pressure turbines ranging from 500 kw. to 2,000 kw. capacity. For a definite quantity of steam passed by the high-pressure engine, the output of the latter, as determined by the resultant total water line when combined with a turbine of the capacity under investigation, is simply added to that developed by the turbine. In obtaining the latter from the total water lines, due allowance must be made for moisture in the engine exhaust and for the pressure drop between engine and turbine usually taken at from 1lb. to 2lbs. The combined output thus developed is compared with the total steam passed by the high-pressure unit, determining the combined economy curves on the right, Fig. 3. As will be observed, the effect of turbine size upon overall economy is, within certain limits, negligible, and may, therefore, be ignored where other conditions favour the choice of a particular turbine capacity. The reason for this close agreement in efficiency is quite plain. Assuming an engine of given size, there is obviously one turbine capacity that will give the best overall results. Variation either way from this best turbine size will cause the engine performance to either improve or decline, as the case may be, the turbine economy being affected in the opposite direction. Thus, for a given departure from the best turbine capacity, the improvement in one element offsets the decline in performance of the other, maintaining the net results virtually constant within a fixed range.

Large Non-condensing Turbines.—These turbines have not hitherto been regarded as competitive to the non-condensing Corliss compound engine since the high-presure piston engines have performed very efficiently. Improvements in the design of the turbine for non-condensing work, have, for all practical purposes overcome the advantage previously possessed by the steam engine. In brief, these results have been accomplished by increased speed ratings and better steam distribution. Tests made three years ago on a 600 kw. non-condensing turbine (obviously of the earlier design), proved the disparity between its performance and that of a first class Corliss compound non-condensing engine to be less than 5 per cent. Later modifications have virtually placed the steam consumption of the large non-condensing turbine on a parity with the engine; and with oil, supplies, maintenance and investment in its favour, the large non-condensing turbine should logically be preferred to the reciprocating engine. Reduction of internal windage losses is imperative in the non-condensing turbine if good efficiencies are to be realised. The drum construction is known to suffer much less loss than the disc type, and is therefore superior. Paradoxical as it may appear, the high-pressure section, which is the most inefficient section of the complete expansion turbine, becomes quite satisfactory in the non-condensing unit. The explanation is simple, inasmuch as the quantity of steam flowing is doubled (with the available energy being halved), so that the ratio of leakage area or annulus to blade height is very much more favourable to economy.

The advanced construction of large non-condensing turbines is shown in detail in Fig. 4, incorporating many interesting improvements in working parts. The smaller non-condensing turbines are not capable of making quite so favourable a showing on the basis of heat efficiency, but, as is now well understood, the steam economy in small operations is not so vital a factor as in the case of large prime movers. The sustained efficiency of the turbine, as compared with the

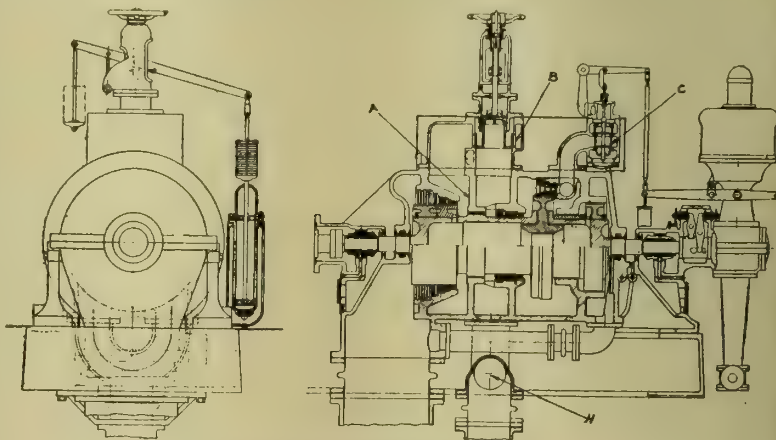


FIG. 5.—AUTOMATIC BLEEDER TURBINE.

vagaries of the engine, needs no emphasis, and it is probable that any lead the small engine may possess initially will disappear unless the engine is constantly governed and cared for, which is the exception and not the rule.

In regard to special applications of the steam end, the design of the automatic bleeder turbine is undoubtedly the most unique of recent developments. It is arranged to profitably serve a combination of independently varying light and heat loads which may be supplied from a single station. Previously the turbine was at a disadvantage under these conditions, where spasmodic stage bleeding was resorted to. The readiness with which the turbine is adapted to the automatic bleeding operation will be appreciated from Fig. 5,

showing a section through such a turbine. The departure from standard construction consists in the main of locating a diaphragm *A* between the intermediate and low-pressure stages, the flow of steam being regulated by a gravity controlled valve *B*. Live steam is admitted at *C*, and on passing through the high-pressure and intermediate sections, part is diverted to the heating system through connection *H*, the surplus passes through the low-pressure section to the condenser. It will be seen that when the pressure in the heating system rises above any predetermined amount as would occur with a decreased heating load (according to the auxiliary or counterbalancing weight used), the valve *B* will be elevated and more of the steam will continue through the low-pressure section of the turbine, developing there an additional amount of work.

There are many manufacturing establishments, and likewise central power plants, where a joint demand for heat (from low-pressure steam) and light occurs. With the growing tendency to economically proportion the plant layout, and with provision for automatic regulation for all variations kept in view, the value of this design will at once be appreciated. Presumably the importance attached to this design will become plainer when we examine the characteristics of the bleeder type. In addition to the economy and the elasticity of application, a wide range in the selection of not only the unit itself, but also of its complementary condenser, is readily seen. To facilitate a proper grasp of its economic possibilities, the triangular chart, Fig. 6, has been developed, enabling a ready appreciation of the relation between the steam bled, the steam supply to turbine (otherwise, draught on the boilers), and the quantity passed to the condenser for a given power load sustained by the unit. These curves have been plotted against brake horse-power on the horizontal, and weight of steam bled on the vertical scale. The solid lines extending up and to the left are lines of constant steam supply and show the increase of available power with decreased bleeding. As will be observed, this is a straight-line relation within certain ranges, the power output increasing at a constant rate as the amount bled decreases, or, what is the same thing, as the amount passing through the low-pressure stages increases, shown by the dotted lines extending up to the right. It will be noted that as the latter reaches a certain value, *i.e.*, about 21,500lbs., the slope of both the dotted and solid lines become steeper, and correspondingly the rate of increase of power output is appreciably diminished. This is due to the opening of the secondary overload valve,

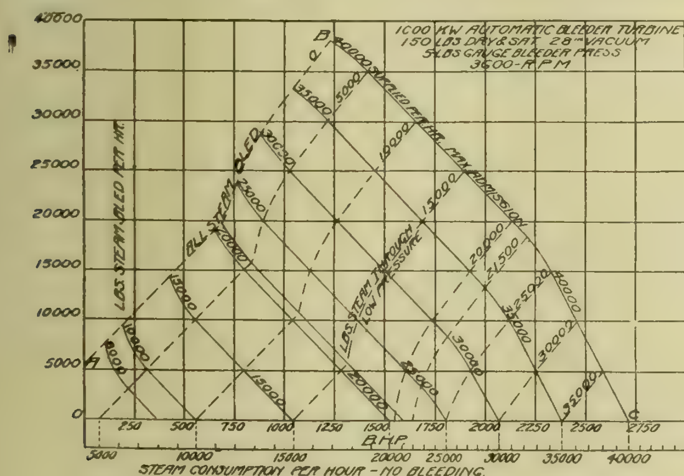


Fig. 6.—Chart Developed to Show Economic Possibilities.

as the bleeder turbine is designed for a normal bleeding demand, and the low-pressure stages are accordingly proportioned to pass a certain quantity of steam. Therefore, when this is exceeded, the turbine output, while still increasing, does not do so at so fast a rate.

To complete the explanation, a supplementary scale, Fig. 6, has been added below that of the brake horse-power, which gives at a glance the total steam consumption of the unit operated strictly condensing (a limiting condition). The other two interesting limits are lines *AB* and *BC*. The line *AB* gives total steam with no work developed in the low-pressure cylinder; *i.e.*, all steam bled at the particular load, and *AB* establishes the boundary for maximum power which may be developed when a predetermined amount of steam is bled. It should be noted that when all steam is bled, as shown by the limiting line *AB*, there is a small difference between the total amount supplied and that accounted for by the quantity bled. On first thought it would seem that these should be equal, but owing to the construction employed, a small portion of the steam leaks past the packing into the low-pressure section, which explains the apparent discrepancy.

A careful study of the chart will furnish a broader view of bleeder turbine characteristics and will considerably assist

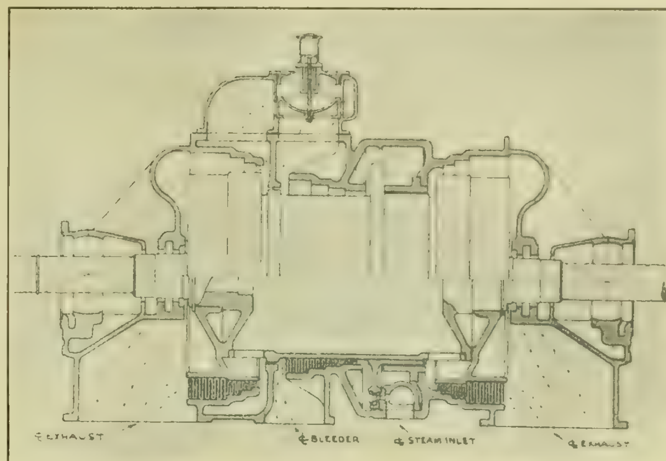


Fig. 7.—Double-flow Type of Turbine.

in the choice of the condenser capacity best suited to the particular set of conditions. In the non-automatic bleeder, the performance could not be so clearly demonstrated as the bleeding is not so closely related to the internal operation of the turbine. This chart obviously applies only to the capacity noted and for the conditions set forth. Evidently a change takes place for any variation in size or nature of operation.

Similar conditions are undoubtedly bound to arise in large undertakings, and the point in question will manifestly be the feasibility of providing large turbines for the purpose. This consideration has already been given due thought, with the result that plans have been prepared for accommodating large turbines to the work, and a diagrammatic illustration of the double-flow construction accordingly arranged, as shown in Fig. 7. These simple illustrations serve to show how fortunately the steam turbine has lent itself to the march of the world's progress.

(*To be continued.*)

Prizes for Miners' Safety Lamps.—It will be remembered that in May, 1911, the Secretary of State for the Home Department announced a prize of £1,000 for an electric lamp suitable for miners which best fulfilled certain specified requirements. The amount of the prize was placed at the disposal of the Secretary of State by a colliery proprietor. Mr. Charles Rhodes, a former President of the Institute of Mining Engineers, and Mr. Charles H. Merz, a member of the recent Departmental Committee on the use of electricity in mines, consented to act as judges, and have now issued their award, which is in the following terms: "We have had submitted to us 105 lamps, varying very considerably in design and construction. We have awarded the first prize to the C.E.A.G. lamp sent in by Mr. F. Farber, 3, Beurhausstrasse, Dortmund, Germany, and inasmuch as a number of other lamps possess considerable merits, we have apportioned the amount offered for competition as follows. F. Farber, 3, Beurhausstrasse, Dortmund, Germany, £600; Attwater Thomas, 22, Welham Square, Brighton, £50; Adolph Bohres, 12, Zieterstrasse, Hanover, Germany, £50; Bristol Electric Safety Lamp Works, 40, Great Smith Street, Westminster, £50; Electrical Company, Ltd., 122-124, Charing Cross Road, London, W.C., £50; W. E. Gray, 19, Archer Street, Camden Town, London, N.W., £50; H. F. Joel, 134B, Kingsland Road, London, N.E., £50; Oldham and Son, Denton, Manchester, £50; Tudor Accumulator Company, 119, Victoria Street, Westminster, S.W., £50."

RECENT DEVELOPMENT OF THE AMERICAN LOCOMOTIVE.*

BY GEORGE R. HENDERSON.

(Concluded from page 208.)

(Concluded from page 208.)

Electric Propulsion.

In the last 10 years the wonderful advancement made by electricity in all lines of work has led some to believe that the days of the steam locomotive are actually numbered and that it would soon become a thing of the past. This belief has been expressed by some men of high standing in political affairs, if not in mechanical, and the great successes attending the application of electricity to street-car lines, suburban transportation, elevated and subway roads have rather brought about a popular opinion harmonising with the above-mentioned assertion.

The difference between the operation of a street-car system, suburban system, elevated or subway railroad is so entirely different from the operation of the average steam railway that there is really little actual comparison between the two. Estimates have been made upon the cost of operation of a steam line, based upon the results found when the elevated railway lines in New York City were electrified, by comparing the new results with those of the old steam operation, and it was only a few years ago that some electrical engineers of considerable reputation advanced the theory that if all the steam railways in the country were to be electrified a saving in the cost of operation would be made which, while not quite equal to that claimed by Mr. Brandeis, would be effected by adopting economies, yet would be well worth considering as means for economical operation.

No one can deny for a moment the great advantage to city and suburban life of the trolley car, and it is this, probably more than anything else, that has given our cities an outlet for their increasing population and made suburban life a happiness instead of a drudgery; but even this has not been altogether without financial disappointment to the electric railway companies, as only a few years back many of them were being sold under foreclosure and only really made money when operating upon a new basis of cost, which had the result of very materially scaling down their fixed charges.

When we consider the application of electricity to the New York Central Terminal tracks in the city of New York, it is often asserted that this substantiates the theory of the devotees of electric propulsion, and this has been made such capital of by electrical engineers in order to enforce their pet schemes, which have been, no doubt, largely developed by over-enthusiasm in their particular line of work. As a matter of fact, the profit of operating the New York Central Terminal line by electricity over the steam lines is not large, and the capital expenditures have been something enormous. It was stated several years ago by the vice-president in charge of electrification that the consequential costs were about four times the actual costs of electrification, by which he meant the arrangement of depôts, tracks, terminals, round-houses, and other facilities which would necessarily enter into the electrification. The fact that there is a margin of profit was shown very clearly in a paper presented to the American Society of Civil Engineers by the official mentioned above, an analysis of which showed that if the actual amount of traffic or the load factor had been less regular there would have been an increased expense instead of an economy. To make this somewhat clearer, we would state that if the power requirements had been so irregular that the facilities of the power-house would need to be doubled to carry the movement over the maximum peaks there would actually have been an extra expense, but, on account of the uniformity of movement, the power-house equipment could be so adjusted that the interest on investment was not so great as to overcome the economy effected in the actual movement of the trains.

On the other hand, it has been but a few months since the New York, New Haven, and Hartford Railroad claimed an increased cost of operation, due to electrification, when this subject was considered for the application of similar conditions to the Boston territory, and, at the best, it would seldom, if ever, be claimed that the economy resulting from electric operation will ordinarily be so great as to make it an attractive financial proposition for the substitution of electricity for steam. There are other conditions, of course, besides the financial part of the problem, such as existed in the tunnel under Park Avenue in New York City, where steam operation was almost intolerable to patrons of the road, not only from the liability to accidents, but from the partial suffocation which everyone experienced in going through the tunnel in hot weather. The question of relieving the city of the smoke of the locomotives was also an important consideration, and it was these features and not the prospect of financial improvement that forced the electrification upon these roads, and we believe that we may well say "forced," as they certainly would never have gone into this project had they not been driven into it by the residents of New York City and the commuters who daily passed through the inferno of the Park Avenue Tunnel.

The consequential damages referred to above can sometimes be reduced or made into an actual asset by utilising the space which would not be available under conditions of steam operation. This is illustrated by the New York Central construction which is now being completed in New York City. The large amount of open space required for the escaping of the gases and steam from the locomotive smokestack can, in the case of electric operation, be reduced to a very small quantity, and the overhead space so vacated by steam and smoke can be utilised for office buildings and other purposes. Of course, this depends largely upon the locality, and there are comparatively few places in the world where this would be as remunerative as in New York City. It is a phase of electrification, however, that should be given due weight when considering the financial returns on any scheme of this kind.

On the other hand, we must consider what actually happens in the way of transportation density and uniformity on many of the railroads in this country, and perhaps we should say on nearly all of them, outside of a few in the most populous districts. It has been claimed that the one requirement for successful financial electric operation was density of traffic, but we believe that uniformity is just as important as density. For instance, let us compare a road like the New York, New Haven, and Hartford Railroad or the Pennsylvania's Atlantic City line. Here the passenger travel is great at all times of the year, and is quite uniform during the day and night, so that frequent train service is required at nearly all hours. In this case we have not only density but uniformity, and, as stated above, it is this item that gives us the saving in the electrical operation to the New York Central's Terminal System. The same is true of the New York Elevated, which runs trains very frequently at all hours of the day and night, maintaining a high load factor, which, while there are peaks, to be sure, yet these peaks are not so far above the average movement as to require an excessive expenditure for installation in the power-house.

From this let us go to the other extreme and consider a line in the West where there is very little local traffic, except that on one or two nights in a week a heavy stock business exists to bring cattle to the following day's market. This business is onerous and exacts and requires high speed and delivery at the expected time without fail; otherwise consequential damages may be assessed against the carrying road. It is not uncommon for this division, which may see two or three trains a day ordinarily, to have 12 or 15 heavy stock trains pass through it in the course of a few hours at some one or more times during the week. These trains are usually sent in fleets in order to ensure better dispatching and also to enable them to arrive in suitable time for the next day's market. The amount of power required on this division at this particular time would be extremely high. If we consider such trains (and they are run at high speeds requiring about 2,000 h.p. for their operation) and that 15 are handled, we see at once that each division power-house must be sufficient to give at least 30,000 h.p. output. The rest of the week the output would probably not be over 3,000 h.p. or 4,000 h.p. at any one time, so that a large amount of machinery must be installed in the power-house to carry this exceptional peak load, and this machinery is non-remunerative for the other six days a week and represents idle investment. This must be repeated at every division power-house which is used to provide power for such a movement, and shows at once the futility of arguing that electrification would be applicable to all roads. The steam locomotives can be bunched, grouped, and transferred from one division to another and make a particularly elastic medium of power transmission, as the next day the locomotives can simply be placed upon another division where their services will be

* Paper presented at a meeting of the Franklin Institute, April 17th, 1912.

needed; moreover, the cost of a horse-power represented by steam locomotives is approximately $15 each, whereas a modern power-house with the transmission lines will cost fully $100 per horse-power, to say nothing of the fact that electric locomotives are nearly double the price of steam locomotives.

These conditions are brought to your attention, not with the idea of belittling by any means the use of electricity for transportation purposes, or of trying to prevent extensions in that line, but are simply presented so that these matters may be so clearly understood that the enthusiasm of some electrical experts may not be permitted to get the best of sound judgment, which will eventually react and injure the cause more than it will help. On the other hand, we would not be surprised at any time to learn that the Pennsylvania Railroad, for instance, would electrify its entire system between New York and Washington. The present New York Terminal is operated entirely by electric locomotives; the subject is being now studied in regard to Philadelphia; the tunnels at Baltimore will certainly soon require heroic treatment; and, in order to prevent the objectionable smoke in the capital of our country, electric traction would be considered a great advantage. These four links in a line 250 miles long, and the density and uniformity of traffic which passes over these divisions, make this quite an attractive subject for electrification, but there can be no comparison between this piece of track and that above described, and which is found in most of our western States.

We have refrained from going into figures on this subject, as statistics are difficult to properly interpret, unless they are given in great detail and carefully analysed, and the different factors entering into the subject are so varied that it requires a great deal of study to actually determine the line between gain and loss. Each individual case must be studied under its own conditions, and only in a general way can we draw deductions from one existing line with which to prognosticate safely the results of some other line. There is no question but that electric traction will increase, but we believe that steam traction will increase still more rapidly, and that the steam locomotive will not be relegated to the museum or the scrap pile during the life of anyone present at this meeting.

There are three different ways in which electric locomotives can be operated: first, by collecting the current as the locomotive moves from either a trolley wire or a third rail; second, by means of storage batteries carried on the engine or tender; third, by means of internal-combustion or other motors generating electricity as required which actuates motors geared to the axles. The first method has certain advantages not enjoyed by the others, and is the one generally employed for handling heavy trains through long distances. The great advantage which results from this arrangement is that the full output of the power-house is available at the motors and the capability of doing work is limited only by the characteristics of the motors installed upon the engine. It is possible with such a combination to obtain much greater tractive forces with high speeds than can ever be hoped for with a steam locomotive, because the latter is dependent upon the capacity of its boiler and fireman, whereas the electric locomotive can receive its power from a plant which will deliver many more horse-power than could possibly be obtained from a locomotive boiler. It is this phase of the question which has been urged so largely in the endeavour to place electric locomotives on heavy grades and mountainous sections, but, outside of some special pieces of track where tunnels make the operation of steam locomotives objectionable, there has been little done in this country along this line, and, although such plans have been investigated, they have not ordinarily been found to be financially attractive. There is no question but what there are great possibilities in this line, provided that the costs are not out of proportion to the benefits developed. The motors, of course, have certain limits, principally governed by their ease of disseminating heat, and it is the heat limit that prevents more power being put through any given motor. There have been cases in the West where even water power, with its generally attractive features, has not been considered as a satisfactory financial proposition; where the cost not only of producing but of transmitting the electric current from the water power to the railroad was found to be too great a financial burden to expect an equivalent return.

For comparatively short lines with dense and uniform traffic, however, there is probably no other method which is likely to be considered, the choice lying between the third rail and the overhead trolley suspension. Both systems have their advantages and disadvantages, but either can be operated satisfactorily, as demonstrated by the locomotives used on the New Haven Road, which, while on the direct current territory of the New York Central, collect from a third rail, and when on the alternating current sections of the New Haven collect from an overhead wire. The motors in this case are single-phase and can be used either on direct or alternating installations. In the latter case the current is transmitted and used at a high voltage, namely, 11,000, while in the direct current the ordinary voltage is 660. It is this difference in voltage that makes it feasible to use third rails with low voltage, which would be considered unwise with the voltages used on the New Haven overhead line. Even at certain points the low voltage direct current must have overhead connections, as at complicated switches and crossings where a continuous third rail is not practicable, but that both systems can be operated satisfactorily is amply demonstrated not only by the trolley car service with its suburban connections, but by the several steam lines which have divisions operated electrically.

There are certain places, however, where it seems impracticable to use satisfactorily either the overhead trolley or the third rail, and these are in freight and classification yards where much shifting is necessary and a great number of switches are encountered. The necessity for men moving on foot over such a yard to do their work in connection with the make up of trains renders the third rail a very serious obstacle, and the presence on top of box cars of brakemen giving signals, &c., renders an overhead wire dangerous and unattractive. For such a condition, either a steam locomotive burning anthracite fuel or with some smoke-consuming device that is effective can be used, or a locomotive operated with a storage battery, which is, perhaps, the most attractive proposition. These batteries can be carried in a separate car or tender and can be recharged and simply picked up by the locomotive, discarding its discharged battery car when necessary. Of course, the expense of such a locomotive is high, and it is possible that some special batteries like the new Edison quick-discharge and recharge battery would alone be acceptable, but the expense, of course, would not be as great as the installation of third rails and overhead wires, and the locomotive has the advantage that it can move on ordinary track, pass into and out of private yards and buildings without any restrictions, and can simply replenish its current when necessary as a steam locomotive would take on coal and water. On account of the great cost of these locomotives, however, which is principally involved in the storage battery, it is not likely that such a system would be developed to any great length of line, but for terminal work and switching around a number of spurs and individual properties it seems like a very attractive proposition.

The internal-combustion motor generating its own current has been made use of in a number of isolated cases, and for branch service and where the service is light and the trains few it answers the purpose admirably. This, however, is also quite an expensive machine, as we must have the power generated converted into electricity and back again by the motors into power, which makes an elaborate system of machinery, and, while it answers the purpose well for branch service, it would not be satisfactory for hauling heavy trains in main line work. The cost of operation of such motors is comparatively low, but the principal saving is in reducing the number of men in the crew. A single car can be operated with two men, whereas the least number that could be run with a steam locomotive and passenger cars would be four men. The uncertain cost of gasolene is also a factor in this method of operation, which is not entirely satisfactory, and when it comes to taking care of such a machine it is certain the car shed will not be a suitable place for doing this work, nor will the round-house be appropriate for the passenger portion of the vehicle. We therefore believe it safe to say that for heavy main line work either the third rail or the trolley system will be found most acceptable, and that the second and third systems above described will be found useful adjuncts for certain parts of a railroad system, but that they cannot be seriously considered for heavy through traffic.

The type of electric locomotive which collects current as it moves, whether by trolley or by third rail, has individual characteristics considerably different from the steam locomotive. Several general arrangements are in use which might be divided ordinarily into three different types: first, that in

which the motors are mounted directly on the driving axles of the locomotive, although this does not mean rigid connection, as they are generally arranged to turn the driving wheels through a flexible connection; second, that in which the motors drive the axles through the medium of spur gearing; and third, that in which the wheels are driven through connecting rods. In the early days of the development of electric locomotives the first arrangement was considered the most desirable, as the centre of gravity was brought quite low and there was an absence of connecting and transmitting machinery. For many years the increasing height of centre of gravity of locomotives has been a bugbear to railroad men, and, when the very low centre of gravity produced by the first arrangement of locomotive was proposed, it was considered that this would be practically ideal. One or two disastrous wrecks, however, led to a more careful study of this question, and one railroad made an elaborate series of tests with different types of steam and electric locomotives, both on straight line and curved, to determine what arrangement of wheels, &c., gave the least strains upon the track.

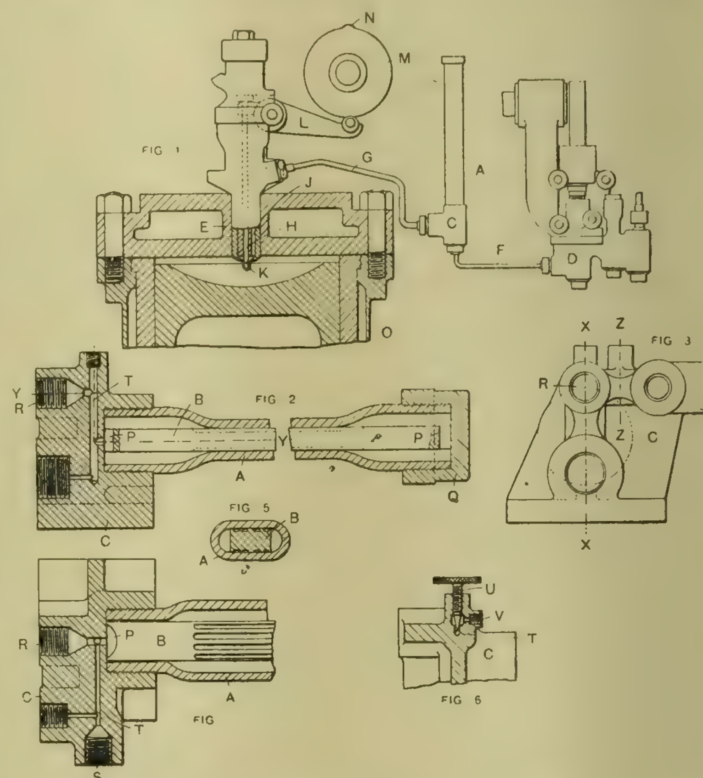
While the high centre of gravity is more dangerous by overturning the locomotive at excessive rates of speed, yet there is no question but what the low centre of gravity puts more stress upon the outer rail of the curve and its tie connections. This may be illustrated by the accompanying diagram, in which it will be seen that while the centrifugal force is the same for locomotives either with high or low centre of gravity with the weight, speed, and radius of curvature the same, yet the high centre of gravity throws an increased weight upon the outer rail, thus forcing it more tightly to the ties and reducing the shearing effect of the horizontal centrifugal force. The later electric locomotives which have been built for the Pennsylvania Railroad are operated by a single motor connected to the wheels by means of an inclined connecting rod. This gives the advantage of concentrating the power into one motor, which is generally more efficient, and also raising the centre of gravity more to the conditions of a steam locomotive. The geared locomotive raises the centre of gravity to a position between the connecting rod and the engine in the gearless type, but does not concentrate the effort into a single motor.

A technical discussion of the details and characteristics of these different types would be out of place in such an article, and all of them are giving very satisfactory results in service, but the principal points of interest have been referred to so that in a general way some idea could be had of the line of thought leading to these three varieties.

As to the question between direct and alternating current, each has its advocates and each has some advantages not possessed by the other. Alternating-current motors, when of the single-phase type, can be so constructed that they will operate on either direct or alternating current, although a motor that is built for operation on only one will be more efficient and lighter than a locomotive built to operate on both circuits. One of the principal reasons for increase in weight in the combination locomotive is due to the fact that it must be provided with both resistance grids for the direct current and auto-transformers for the alternating current. With the direct current, the speed regulation is arranged by using the series or parallel operation in connection with reducing the voltage by passing it through resistance coils or grids. This is wasteful and is only intended to be used in starting and under certain conditions of slow speed. The alternating current varies the voltage by means of taps taken off from different parts of the transformer coil, and is free from the wasteful resistance of the direct current means of regulation. Both types can be coupled up to provide multiple unit control, so that one, two, or more sections can be used in accordance with the needs of the train to be hauled. The leading unit only need be occupied by the motorman and assistant. With such a combination there is almost no limit to the amount of power which can be developed, as each unit is limited only by the heat characteristics of its motors. Regardless of the great power which can be supplied by such units, however, the service so far performed in this country is nearly all passenger, and little freight work is being done by electric locomotives on trunk lines. Of course, this statement is not strictly true if we consider such cases as the Baltimore tunnels of the Baltimore and Ohio, the tunnel under the river at Detroit, and the Sierra Nevada tunnel of the Great Northern, and other points where steam operation would be particularly objectionable; but, outside of a few special cases such as above mentioned, the electric service is confined almost exclusively to passenger transportation.

DEVICE FOR SUPPLYING FUEL TO OIL ENGINES.

A METHOD of supplying liquid fuel to internal-combustion engines of the kind in which the fuel is injected suddenly under extremely high resilient pressure into a highly-compressed charge of air in the cylinder has recently been designed and patented by Mr. James McKechnie, of Messrs. Vickers, Ltd., Naval Construction Works, Barrow-in-Furness. The apparatus employed for injecting the fuel comprises a tube, the walls of which are made so as to yield slightly under high internal pressure, obtained by the action of a fuel delivery pump while the cylinder injection valve is held closed, and, on the opening of this valve, to cause a contraction of the tubular volume and force a definite charge of fuel into the cylinder. For this purpose the tube is made of elliptical or flattened cross-section, so that, on subjecting it to the high internal liquid pressure, the walls tend to take a cylindrical form, and the volume is thus increased to admit



DEVICE FOR SUPPLYING FUEL TO OIL ENGINES.

the charge, the amount of liquid admitted being determined by the pump. When the injection valve is opened, the tube walls return suddenly to their flattened form and force into the cylinder all the excess liquid admitted by the previous expansion of volume.

To prevent expansion of the tube until a predetermined high pressure has been reached a distance piece is placed within the tube which prevents the full contraction of the walls to their free flattened form, so that, on the relief of the internal pressure, they contract upon the distance piece with great force. When the internal pressure is sufficient to overcome this initial force the tube begins to expand. The distance piece is in the form of a rod bridging the shorter diameter of the tube throughout its length, but leaving space for the liquid at each side and having channels to allow it to reach the flattened surface of the tube. By this device the injection of the full fuel charge is, it is claimed, ensured at each opening of the valve, as even at the end of the operation the contracting pressure of the tube walls is greatly in excess of the pressure inside the cylinder.

Fig. 1 is a general view, showing the application of the pressure tube to an engine. Fig. 2 is a longitudinal section of the pressure tube device, taken on the line X—X of Fig. 3,

which is an end elevation of the same. Fig. 4 is a longitudinal section taken on the broken line Y—Y of Fig. 2. Fig. 5 is a cross-section of the tube, and Fig. 6 is a detail section on the line Z—Z of Fig. 3. A is the pressure tube. B is the distance piece placed within the tube to prevent its full contraction and produce an initial contracting pressure. C is the tube fitting by which connection is made to the pump D and the engine cylinder. In the general arrangement shown in Fig. 1 the pressure tube A is placed between the pump D and the engine cylinder, to which it is connected by the pipes F and G. The pump D is capable of producing an extremely high pressure. The liquid fuel is admitted to the cylinder under the extreme pressure due to the contraction of the tube walls, which have been expanded by the liquid forced in by the pump. The admission of the liquid fuel is controlled by the valve H at the cylinder end of the inlet passage J, the liquid passing through fine holes in a spraying cap K over the end of the passage. The valve is operated by the lever L and cam M, the cam having a small projection N on a circular periphery, so that the opening of the valve is almost momentary, and during the injection of the fuel the piston O has time to move only a short distance.

Referring to Figs. 2 to 6, the tube A is shown of considerably flattened form except at its ends, which are left circular, and the distance piece B is made with longitudinal grooves extending almost throughout its length and permitting the liquid readily to reach the flattened tube walls and to be expelled on the contraction of the tube. The ends of the grooves are exposed at the round ends of the tube, so that free communication is established throughout the tube. The extremities of the distance piece are arched at P to provide a cross passage at the ends. One end of the tube is covered by the screwed cap Q, the fitting C being secured on the other end. The connection to the pump is made through the inlet R and that to the engine through the outlet S. The tube and all the openings in the fitting C are inter-connected by the passages T. A needle stop valve U, shown in Fig. 6, is provided at the air vent V. This air vent should be placed at the highest point of the tubular pressure device.

The parts are so constructed that the initial pressure which must be exceeded before the tube A begins to expand is about 2,000lbs. per square inch, and the maximum pressure, when the tube receives the full charge, may be from 4,000lbs. to 6,000lbs. per square inch. The tube must therefore be made of substantial thickness to provide for such high pressures by the distortion of its walls. At these pressures it is very desirable that there should be as few moving parts as possible, in order to avoid leakage, a small loss in the charge largely decreasing the efficiency of the engine. The tubular pressure device allows of ready application of the extremely high resilient pressure desired in order to provide for the sudden injection of the liquid fuel, without the use of a spring-controlled plunger or other reciprocating or sliding member.

THE ELECTRIC FURNACE FOR TEMPERING TOOL STEEL.

THE change from the use of the old time carbon steel to the present day special steels, containing vanadium, nickel, chromium, tungsten, &c., is, says B. Henrikson, in a paper read before the Railway Tool Foremen, Chicago, working a revolution in the methods which were formerly in vogue for tempering carbon steels. Temperatures are demanded which cannot be successfully attained in the ordinary forge without danger of altering the composition of the steel.

The best results so far obtained in a furnace requiring fuel have been brought about in the following manner. The tool to be tempered is placed in some sort of a receptacle, and all the space between it and the walls of the receptacle is filled with finely divided charcoal. Then the receptacle is sealed up so as to be impervious to gas or air and placed in the furnace. The temperature of the furnace is brought to that required to give the tool the desired degree of hardness (about 2,100° Fah.) and this temperature is maintained until the heat has had a chance to penetrate entirely through and the whole mass is at one temperature. This requires about two hours. Then the receptacle is removed from the furnace and the tool taken out and plunged into an oil bath. The charcoal does not adhere to the steel. By this method an excellent job is obtained. An even heating of the steel prevents spring, thus giving accuracy to the result. By packing in charcoal and sealing, exposure to air, gas, or fuel is prevented, and consequently the chemical composition is not altered.

The nearest approach to the results obtained in the manner described is obtained by the use of the electric furnace. This supplies the place of the sealed receptacle, and as it requires no blast or fuel to obtain a high temperature the danger of altering the chemical composition is obviated. The highest desired temperatures can be obtained and by varying the strength of the electric current any desired degree of temperature can be obtained or maintained constant.

There are two distinct types of electric furnaces. One type is so constructed that it forms an open vessel in which is placed a substance which becomes a liquid at the hardening temperatures. The substance generally used consists of barium chloride and potassium chloride mixed in the proper proportion, this proportion depending upon the metal to be hardened and the temperatures desired. For very high temperatures only pure barium chloride is used. In some shops for temperatures below 700° C. (1,292° Fah.) pure sodium nitrate is used and sometimes a mixture of sodium nitrate with potassium chloride. The author's experience does not cover use of nitrates. In practice it has been found that one objection to the use of this method is that the tongs used in removing the tools from the bath decompose and tiny particles of iron collect on cutting edges, and when plunged these particles become so hard that they can be removed only by grinding. Often it is impossible to grind them off without injuring the tool. Aside from this trouble, very good results are obtained in this furnace. The outer walls of the furnace are never hot, so there is no danger from fire, and also the cooling bath may be placed close to the furnace, thus reducing to a minimum the time between removing and plunging.

The other type of furnace does not make use of a heating bath, but consists of a box-like structure which may be closed so as to exclude the outside air. The heat is generated by the resistance of carbon " resisters " located in the side walls of the furnace. The current strength and thus the temperature of the furnace is varied by altering the area of contact of these resisters. The greater the current which is allowed to flow the higher is the temper obtained. It is generally found that if the furnace is entirely closed a reducing action takes place, so a door is provided for the admission of outside air until the action is neutral. Care must be taken in using this furnace that too much air is not allowed to enter, for then oxidation takes place and the steel to be tempered will scale.

The electric furnace has this further distinct advantage over any kind of a furnace making use of a blast. With such a furnace it is next to impossible to maintain the temperature uniform in all parts so that the tool to be hardened will become hotter on one side than it is on the other, and thus will be sprung out of its true shape. With the electric furnace no draught is required so that a purely soaking action takes place and the tool is evenly heated.

Granted that the electric furnace can produce just as good work as can be obtained with the most improved practice in the use of the furnace requiring fuel, we must still consider the following points in the operation of the furnace. The furnace is simplicity itself, so that highly skilled and consequently highly paid labour is not required to operate it. By using a pyrometer and knowing the proper temperature at which a given steel is to be hardened there is no longer the necessity to depend upon the judgment or experience of any one man, thus cutting down labour cost.

Speed of German Trains. The speed of German passenger trains is not usually remarkable, says the American Consul at Nuremberg. The so-called " fast " trains and " hurry " trains (for the first of which an extra charge is made) are both ordinarily deliberate in their movements, and accommodation trains and " locals " often spend much time between stations, usually in sight of each other. The new summer time-table for the German State systems, he says, shows some acceleration in speed, principally, of course, of the through trains. The fastest train in Germany is the so-called " D-Zug 20 " between Berlin and Hamburg, which maintains an average speed of 55·177 miles an hour.

INDUSTRIAL AND TRADE NOTES.

Engineers' Wages Advanced.—It is officially announced that as a result of the negotiations with the Federated Admiralty contractors, the wages of the engineers have been increased by 1s. per week, making the current rate 39s. per week of 48 hours. A further advance of 1s. per week will take effect in January next.

New Locomotives.—Fifty powerful locomotives with superheating apparatus are being constructed at the Hyde Park works of the North British Locomotive Company for the Great Central Railway Company's mineral traffic at the Immingham Docks. Of these 10 are practically completed. The engines are of the 4—4—0 type. The weight of each locomotive, with tender, is 94 tons, and with coal and water about 110 tons.

Trade Circulars.—The St. Helens Cable and Rubber Company, Ltd., send us price list of a new form of their patent cab tyre sheathed cable, for which special qualities of endurance against wear, tear, and climatic differences are claimed. From Messrs. Bowes, Scott, & Western, Bradways Chambers, Westminster, we have received a circular descriptive of their water softening apparatus, with illustrations of several installations.

Light Railway.—The Board of Trade have recently confirmed the under-mentioned Order made by the Light Railway Commissioners: Quarry Bank and District Light Railway (Transfer, &c.) Order, 1912, transferring to a company the powers conferred upon the Urban District Councils of Quarry Bank, of Brierley Hill, and of Rowley Regis by the Quarry Bank, Brierley Hill, and Rowley Regis Light Railway Order, 1903, and amending that Order, and for other purposes.

Electricity in Textile Mills. — The Welsh Flannel Company at Holywell, which comprise a weaving shed and piece-drying, tweed-finishing, carbonising, dyeing and wool-washing rooms, is being equipped with electrical plant to drive the looms and spinning machinery in the works in place of a combination of gas, steam, and water power. Two engines, of 200 h.p. and 100 h.p. respectively, have been supplied by Messrs. Belliss & Morcom, and the electrical apparatus has been provided by the Lancashire Dynamo and Motor Company.

Openings for British Trade in Honduras.—In his annual report on the trade of Honduras the British Consul comments on the fact that practically all the industries of the country are in the hands of United States capitalists, and that the States also handle the greater part of its trade. The latter he, in part, attributes to the fact that at present it takes some eight months for an order given in the United Kingdom to reach Honduras, while the United States can supply the same in a similar number of weeks. The business terms offered by United States firms are not so advantageous as those in the United Kingdom, however, and the Consul states that there is a good opening in Honduras for British firms dealing in general merchandise. Honduras has been almost entirely neglected by foreign mining interests, but its great wealth, says the Consul, is now attracting some attention both in New York and London. He considers there are openings for investment of British capital in the mines, agriculture, and public works, and adds that the Government are anxious to attract foreign and especially European capital.

Oil as a Substitute for Coal.—The recent coal strikes in Germany have had the result of intensifying public interest in that country in the question of substitutes for coal. In many industrial works requiring a large amount of coal, says the British Consul-General for Westphalia, and the Rhenish Provinces, steam engines have of late years been partly replaced by engines worked with benzol and oils of various kinds. As coals become more expensive technical improvements in oil engines are being made, which will in time cause the use of coal to decrease. Oils of all kinds, particularly petroleum, says the Consul-General, suggest themselves as substitutes for coal. Of late the Diesel engine has attracted a great amount of attention, and in connection therewith the improvements in the process of obtaining oils from coal. It is only quite recently that the difficulties experienced with these oils have been overcome. Since the last coal strike many firms have turned to oil in order to lessen the danger of running short of coal, and many firms have made slight alterations in portions of their furnaces in order to be able to burn the oil fuel in case they run short of coal. Coal tar oil promises to have a great future as a general fuel.

Labour Outlook in New Zealand.—Although business is reported as fairly good in all parts of the Dominion of New Zealand, there are disturbing elements which cause disquietude, says the American Consul-General at Auckland. As in other parts of the world, labour seems to be in a state of unrest. The labour unions are fast cancelling their registrations under the Conciliation and Arbitration Act, in order to be able to stop work at any time should they deem it advantageous to do so. At the same time, some of them are joining the New Zealand Federation of Labour recently organised, which advocates the principle of the general strike. Under these conditions employers, especially contractors, are becoming timid, and hesitate to engage in new undertakings. The total foreign trade of the Dominion last year was £37,510,100, composed of imports of £19,007,400, and exports of £18,502,700. While the value of imports exceeded that of the preceding year by over £2,100,000, the value of exports diminished over £3,000,000, converting the favourable balance of trade in 1910 of nearly £5,000,000 to an unfavourable one in 1911 of over £500,000.

Examinations for Colliery Managers.—The Board for Mining Examinations have issued a notice relating to the arrangements under the Coal Mines Act, 1911, for the examinations for certificates of competency as manager and under-manager of coal mines, and for certificates of qualification as mining surveyor which have been approved by the Secretary of State. Two examinations will be held in each year commencing on Tuesday in the last complete week of May and in the last complete week of November respectively. Each examination will be held simultaneously at the following centres: Sheffield, Edinburgh, Newcastle, Wigan, Cardiff, Birmingham. The first examination will take place next November. Candidates will be expected to sit for examination at the centre in the district in which they have chiefly gained their practical experience. The Board desire it to be made specially known that every candidate, whether for a first or second class certificate, will be required to possess a first-aid certificate of the St. John Ambulance Association, or the St. Andrew's Ambulance Association, or other society or body approved by the Secretary of State, and a fireman's certificate under Section 15 (1) (b) of the Coal Mines Act, 1911. A list of subjects in which the candidates will be examined is given in the notice.

American Coal Production in 1911.—A report recently issued by the United States Geological Survey states that the total coal production of that country in 1911 amounted to 496,188,308 net tons (2,000lbs.), valued at the mines at $625,910,113. Of this production, anthracite (Pennsylvania) amounted to 90,464,067 tons, valued at $174,952,415, and bituminous coal and lignite to 405,724,241 tons, valued at $450,957,698. The total production in 1911 decreased 5,408,070 tons, or a little over 1 per cent. in quantity, and $3,646,908, or a little over 0·5 per cent. in value, as compared with 1910. The decrease is attributed wholly to the depressed condition of the iron and steel trade in 1911, which was reflected in the decreased production of coke. The three leading coke-producing States alone showed an aggregate decrease of nearly 9,000,000 tons of coal. The total number of men employed in the coal mines of the United States in 1911 was 722,322. The average production per man was 3½ tons a day in the bituminous and lignite mines, and 2·13 tons a day in the anthracite. The time lost by strikes in 1911 was insignificant. The average price for bituminous coal was 1 cent per ton lower in 1911 than in 1910 and that of anthracite was 3 cents higher.

Machinery Exhibit at Olympia.—The International Engineering and Machinery Exhibition to open at Olympia on October 4th, which is being organised by the Machine Tool and Engineering Association, Ltd., promises to be exceptionally interesting. The stands will be arranged so as to carry out the idea of a large, well-equipped engineering workshop. The impression often conveyed by exhibitions is of a large number of signs and partitions, and that live exhibits require careful search. In the Engineering Exhibition no enclosed offices or partitions will be allowed on the stands. A further important point in connection with this exhibition is that for the first time in British engineering the trade itself has decided how and what it will exhibit so that the display will not be a mere trade show, but a large, well-ordered aggregation of machinery controlled in the best interests of the exhibitors. The exhibits will include machines for turning out wire nails in millions, without any waste material whatever, and automatics turning out screws, nuts and bolts quicker than one can think of them. An outstanding exhibit will be a bone boiler, which will be shown in operation. A distinctive feature will be the comparative absence of noise, demonstrating the progress made in recent years by cut gearing and other appliances to reduce this nuisance. There will in all be a working area of upwards of 40,000 square feet, and close upon 300 firms will be represented.

Amalgamated Society of Engineers.—The report states that the membership had reached 134,267, an increase of 7,063 for the past month. The Executive also make the following statement with regard to the Parliamentary voluntary fund: "Again the Committee of management for this fund desire to draw the attention of members to the absolute necessity of this fund being considerably augmented if we are to continue the work of Labour representation. Although the Government has made provision for the payment of Members we have still to meet the expenses incurred in holding the constituency won, as the cost of registration and organisation is no small item. Further, we have our responsibility to the Labour Party, and other contributions to the Parliamentary Fund, and our present income is far from meeting the expenses

necessary. We are prohibited by law from asking for levies as in former years, and are compelled if we are to continue in this work to ask for increased contributions to our voluntary fund. Whether we, as a Society, shall bear our share of expenses of the Labour Party, and retain the constituencies rests with the members, as the prompt response to this appeal will decide the position as regards the A.S.E. In order that you may know our financial position we may inform you that the Executive Council, General Office Trustees, General Secretary, and Mr. C. Duncan, M.P., have become guarantors to the bank for an overdraft of £1,000 on behalf of the members to meet our liabilities."

Canal Development in Germany.—A report made by the British Consul General for Westphalia and the Rhenish Provinces gives some interesting particulars respecting the rapid development of German canals. Encouraged by the economic success of the Dortmund-Ems and Kiel Canals, he says, the Government proposes to continue building waterways wherever feasible. It is proposed to build a trans-Continental canal due east beyond Dortmund. Further, all the rivers running from south to north into the Baltic and North Sea are to be joined together by a large canal running from west to east, thus bringing the east and south-east in direct communication with the North Sea viâ the Rhine-Herne-Dortmund-Emden Canal. The construction of the Rhine-Weser Canal and the enlargement of the Berlin-Stettin Canal have already been taken in hand. The River Ruhr, at Essen, in Westphalia, is to be deepened and widened. At Bingen, on the Rhine, the dangerous Bingen Loch is to be made more easily navigable. The Rhine itself, which is only navigable for large ships as far as Strassburg, is to be made navigable as far as Basel. The Mosel and Saar, tributary rivers of the Rhine, are also to be deepened and canalised. By this means the industrial districts of Alsace-Lorraine and Luxemburg will gain immensely. The River Lahn, an important tributary of the Rhine, is to be deepened and canalised at a cost of £1,000,000, in order to enable some of the Rhine ships to navigate up the Lahn. The Consul-General adds that so far experience has proved that canals have not in any way lessened the Government income derived from State railways.

Employment in July.—The labour department of the Board of Trade report that employment in July continued good, and showed some improvement on a year ago. The percentage of trade union members unemployed, so far as reported to the Department, was the lowest in any July since 1900, a year of exceptionally good employment. The upward movement in wages continued. Compared with a month ago there was an improvement in the pig-iron, tinplate, and shipbuilding trades. Employment in the engineering trade continued very good, with much overtime. The coal mining and building industries remained about the same as in June. Compared with a year ago the principal industries showed an improvement, which was most marked in the pig iron and steel trades. In the 390 trade unions, with a net membership of 863,456, making returns, 22,222, or 2·6 per cent., were returned as unemployed at the end of July, 1912, compared with 2·5 per cent. at the end of June, 1912, and 2·9 per cent. at the end of July, 1911. Returns from firms employing 421,839 workpeople in the week ended July 27th, 1912, showed a decrease of 0·3 per cent. in the number employed, and of 0·8 per cent. in the amount of wages paid, as compared with a month ago. Compared with a year ago there was an increase of 2·1 per cent. in the number employed, and of 6·1 per cent. in the amount of wages paid. The changes in rates of wages reported for July were all increases, and amounted to £13,000 per week on the wages of the 290,000 workpeople affected.

Board of Trade Intervention in Labour Disputes.—The Council of the London Chamber of Commerce has adopted and has forwarded to the President of the Board of Trade a report by a Special Committee relative (*a*) to action taken by the London Labour Conciliation and Arbitration Board during recent labour troubles in London; (*b*) to the relations between that Board and the Board of Trade; and (*c*) to the desirability of forming district conciliation boards in various ports and centres in the United Kingdom on a voluntary basis and on similar lines to those adopted successfully by the London Board. The report deals in detail with the subject matter of the reference. Complaint is made that notwithstanding the existence of awards made by the London Board in respect of the lightermen of the Thames by which employers and employed were bound to give notice of termination and to refer any disputes to that Board, the Board of Trade intervened between the parties and concluded a fresh arrangement with them during the dock strike of 1911. This was the first instance during the existence of the Board, extending over 20 years, where one of its awards had been violated and where a Government Department had directly intervened in a matter which was properly within the sphere of a district conciliation board. This, it is pointed out, was the more remarkable as under the Conciliation Act of 1896 its intervention would only be justified where "adequate means do not exist for having disputes submitted to a conciliation board for the district or trade." The report also recommends that a conference of representatives of voluntary district and other conciliation boards now in existence should be held with the object of establishing additional boards where not already provided for. The Council of the London Chamber of Commerce decided to forward the report to the President of the Board of Trade with an expression of opinion "that the direct intervention of the Government in labour disputes where voluntary conciliation boards exist is most undesirable except in cases of national emergency."

Output and Working of Mines in 1911.—The annual report of Mr. R. A. S. Redmayne, chief inspector of mines, just issued by the Home Office, gives particulars of the output and working of the mines of the United Kingdom during the year 1911. According to this, the total number of persons employed in and about all the mines of the United Kingdom was 1,096,238, of whom 1,067,213 worked at the 3,325 mines under the Coal Mines Act, and 29,025 at the 652 mines under the Metalliferous Mines Act. Compared with 1910 there is an increase of 17,806 persons at the mines under the Coal Mines Act and an increase of 349 persons at the mines under the Metalliferous Mines Act. At the quarries under the Quarries Act there were 82,863 persons employed. Compared with 1910 there is a decrease of 2,974 in the number of persons employed at quarries. The total output of minerals at the mines under the Coal Mines Act was 285,942,232 tons, of which 271,878,124 were coal, 2,482,846 fireclay, 7,886,898 ironstone, 3,116,803 oil shale, and 577,561 sundry minerals. Adding 13,775 tons from open quarries, the total output of coal was 271,891,899 tons, which is an increase of 7,458,871 tons on that of the previous year, and the greatest output yet recorded. The average output of mineral at mines under the Coal Mines Act was 331 tons per person employed underground, an increase of three tons on the preceding year. The total output of minerals at the mines under the Metalliferous Mines Act was 3,222,950 tons, of which 1,823,795 tons were iron ore. The total quantity of stone and other minerals obtained from the quarries under the Quarries Act was 5,810,766 tons, of which 5,316,525 tons were iron ore. Adding to the produce of mines and of quarries over 20ft. deep 492,206 tons obtained from shallow open workings we arrive at a total output of iron ore of 15,519,424 tons. At the mines under the Coal Mines Act there were 1,212 separate fatal accidents, causing 1,265 deaths. Compared with 1910 there is a decrease of 30 in the number of accidents, and of 510 in the number of deaths. But in the year 1910 occurred the two unusually great colliery disasters of Whitehaven and Hulton, in which respectively 136 and 344 persons lost their lives. At the mines under the Metalliferous Mines Act there were 41 fatal accidents, which caused 43 deaths. Compared with 1910, there is an increase of three in the number of fatal accidents, whilst the number of deaths was the same. The returns under Section 1 of the Notice of Accidents Act, 1906, show that the total number of non-fatal accidents occurring during the year which disabled for more than seven days was 166,153 at mines under the Coal Mines Regulation Act, by which 166,616 persons were injured; at mines under the Metalliferous Mines Act, 1750, by which 1,744 persons were injured; at quarries under the Quarries Act, 5,167, by which 5,189 persons were injured. Compared with 1910, there is an increase of 7,574 in the number of persons injured at mines under the Coal Mines Act, of 148 at mines under the Metalliferous Mines Act, and of 14 at quarries under the Quarries Act. The death rate of the underground workers at the mines under the Coal Mines Act was 1·29 per 1,000 persons employed, as against 1·91 in 1910. The total number of deaths from accidents at mines under the Coal Mines Regulation Act is the lowest since 1907, and from explosions the lowest since 1904. Mr. Redmayne states that death rates from all accidents underground and from surface and underground combined for the year 1911 are the lowest on record.

Two Men "Gassed" at an Ironworks.—A double fatality occurred at the Cargo Fleet Ironworks, Middlesbrough, on Tuesday last, Mr. Henry Watts, assistant blastfurnace manager, and a labourer, losing their lives through being "gassed," while a third man, a labourer, lies in hospital in a dangerous condition. The fatality occurred while the flues of the blastfurnaces were being cleaned out. It is not known whether the two labourers entered the flue together, but they were both "gassed" on entering the flue. Mr. Watts, who was near, discovered their dangerous condition, and immediately entered the flue to rescue them. He, however, was soon rendered unconscious by the deadly fumes. An alarm was raised and the men got out. Artificial respiration was at once applied, which resulted in only one of the three men being brought round.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Circular saw benches and attachments thereto. James. 13921.
Internal-combustion engines. Tacchi. 17117.
Transmission gear for motor-vehicles. Fergusson, Spurrier, and Leyland Motors, Ltd. 17186.
Carburetters for internal-combustion engines. White. 17193.
Carburetters for internal-combustion engines. Brown, and Brown and Barlow, Ltd. 17203.
Helical spur gearing. Alquist. 17244.
Machines for grinding cam faces. Pittler Universal Rotary Machine Syndicate, Ltd. 17367.
Steam generator. Christians. 17403.
Process and apparatus for removing the slags from ingot iron and ingot steel in open-hearth furnaces. Stobrawa. 17434.
Utilisation of peat in gas producers. Societa per l'utilizzazione dei Combustibili Italiani & Civita. 17436.
Apparatus for raising or lowering materials. Heenan & Froude, Ltd., and Hood. 17457.
Means for preventing overwinding of elevators or lifts. Atkinson. 17470.
Locking nuts on bolts. McDonald. 17599.
Methods of wire drawing. Dempster. 17722.
Grates for boiler furnaces. Fuller. 17769.
Soot cleaners for boilers. Eichelberger. 17819.
Screw and nut mechanism. Sir W. G. Armstrong, Whitworth, and Co., and Murray. 17877.
Burners for drying moulds. Deutsch Luxemburgische Bergwerks und Hütten Akt.-Ges. 17899.
Evaporating apparatus. Sanborn. 18216.
Gearing for preventing overwinding in colliery engines. Walker. 18261.
Movement indicator for marine engines. Alexander. 19100.
Manufacture of armour plates and other steel articles. Vickers, Ltd., and Benthall. 19458.
Furnaces. Royston. 20890.
Sand-papering, emery-grinding, and analogous machines. Jarvis. 20957.
Castings of tool steel. Van Den Kerckhove, Perier, Venail, Grenier, and Jansson. 20969.
Worm and wheel-driving mechanism. Dallison. 21492.
Centrifugal pumps. Michell. 21611.
Journal bearings. Michell. 23496.
Internal-combustion engines. Shaw. 27942.
Refuse burning furnaces in conjunction with steam boilers. Marks. 28021.
Lift valve for controlling the flow of fluids. Ullmer. 28127.
Turret rotating mechanism. Herbert & Vernon. 28441.
Method of compressing metal turnings or filings into solid blocks, and machinery to be used for such purpose. Punnett. 28574.
Engine speed-controlling gear for preventing overwinding in collieries. G. Inglis & Co., and Inglis. 28785.
Means for converting a continuous rotary movement into a step-by-step rotary movement. Dusseris. 29210.
Vertical liquid fuel burning devices. Falkenberg. 29369.

1912.

Recovery of tin from tin-bearing ores by conversion into volatile tin compounds. Richards. 56.
Automatic lubricating apparatus for explosion motors. Van Lynden. 1008.
Screws. Steinman. 1563.
Speed-changing, reversing, and braking gear. Perret. 1853.
Railway train controlling systems. Ullrich. 2852.
Cotter pins. Germonprez. 3122.
Field tube steam superheater for smoke tube boilers. Becker. 4926.
Means for preventing overwinding and overspeed in mine shafts. Hirst. 5171.
Well boring rotary bits. Dodge. 5458.
Steam heating apparatus. Wagner. 6107.
Safety hook. Evans. 7216.
Gear cutting machines. W. P. Eglin, Ltd., and Eglin. 7513.
Controlling gear for winding and hauling engines. Melling. 7833.
Means for indicating the opening and closing movements of valves at a distance. Soc. Courtaud, G. Garnier, Gil, et Cie. 7852.
Measuring devices of apparatus for carburetting air. De Laitte. 8213.
Method for insulating of piping. Lyman. 8292.
Manufacture of aluminium nitride. Soc. Generale des Nitrures. 8347.
Mountings for turbine generators. Ljungstrom & Aktiebolaget Ljungstroms Angturbin. 8455.
Four stroke cycle oscillating cylinder internal-combustion engines. Maybach. 8766.
Hoisting apparatus. Forman. 9291.

ELECTRICAL, 1911.

Electrolytic cells. Threlfall. 10142.
Fusible cut outs for controlling electric circuits. Hope. 14803.
Application of radioactive phenomena to telephony. Vojen. 17027.
Electric motors and dynamos. Cooper. 17716.
Automatic telephone exchange systems. Western Electric Company. 18648.
Regulators for electrically-driven ring spinning and doubling machines. Siemens Bros. Dynamo Works, Ltd., and Kieffer. 19083.
Speed regulation of electric motors. Wagner. 19362.
Receiving apparatus for use in radio telegraphy and telephony. Bower. 19829.
Switches for high-tension electric currents. Marconi's Wireless Telegraph Company, Ltd. 26153.
Accumulator plates. Zyttkowski. 26556.
Electric maximum and minimum excess voltage switches. Eisemann, and Ernst Eisemann & Co., Ges. 27729.
Dynamos. Juston. 28750.

1912.

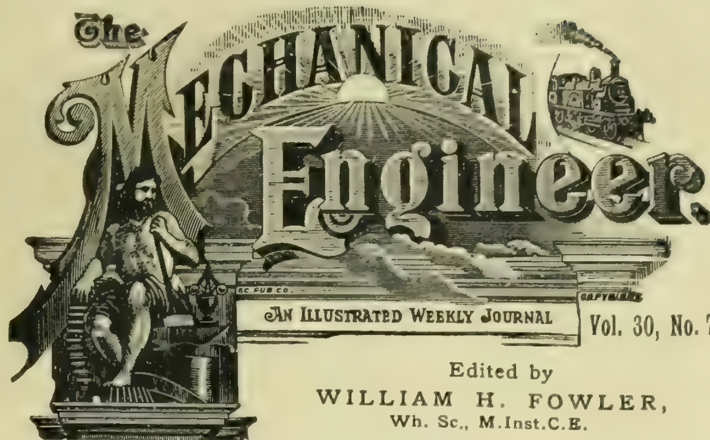
Registering calls between telephone exchanges provided with automatic selectors. Siemens Bros. & Co. 1658.
Receiving apparatus for electric oscillations. Ges. fur Drahtlose Telegraphie. 2383.
Electro magnets. Barnes & Jensen. 2702.
Brush shifting mechanism for dynamos. British Thomson Houston Company, and Young. 4688.
Negative electrodes for electric searchlights. Geb. Siemens & Co. 4780.
Suspension of overhead conducting wires for electric railways. Bloxam. 6670.
Electric igniters. Born. 8327.
Speed regulation of alternating-current induction motors. Siemens Bros. Dynamo Works, Ltd. 9134.
Telephone systems. Derriman. 15135.

METAL QUOTATIONS.

TUESDAY, AUGUST 20TH.

Aluminium ingot	80/- per cwt.
„ wire, according to sizes, &c. ......from	102/- „
„ sheets „ „ ...... „	120/- „
Antimony .... £28/-/- to	£29/-/- per ton.
Brass, rolled	8½d. per lb.
„ tubes (brazed)	11½d. „
„ „ (solid drawn)	9¾d. „
„ „ wire	8⅝d. „
Copper, Standard	£78/7/6 per ton.
Iron, Cleveland	61/6 „
„ Scotch	67/6 „
Lead, English	£19/17/6 „
„ Foreign (soft)	£19/12/6 „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£8/5/- per bottle
Silver	28⅝d. per oz.
Spelter	£26/10/- per ton.
Tin, block	£209/15/- „
Tin plates	14/7½ „
Zinc sheets (Silesian)	£29/5/- „
„ (Stettin; Vieille Montagne)	£29/7/6 „

Curious Explosion. -- An inquest was held at West Bromwich, on the 13th inst., respecting the death of a man who died from injuries sustained the same day while at work at Accles & Pollack's, Ltd., Oldbury. The man was passing one of the muffles in which a tube was drying when an explosion occurred and the tube was blown out, striking him, and injuring him so badly that he died a few hours after. It was stated that the tube was wet, and must have been blocked with dirt, so that pressure was generated in the tube until eventually the pressure blew out the plug of dirt and the tube was then shot out of the muffle like a rocket, with the result stated. The jury returned a verdict of "Accidental death."



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Electricity in the Home.

THIS year has witnessed something more than an isolated attack on the domestic field for the use of electricity. Not all the attacks have been carefully correlated, but on the whole they fit into a general campaign which received the sanction and practical assistance of the Institution of Electrical Engineers. In spite of all the talk about educating the people we shall be quite safe in thinking that electrical engineers have entered upon this campaign for commercial ends. This is quite as it should be, and is mentioned here simply to emphasize the fact, which is so often lost sight of, that the application of electricity to various uses in our homes should be treated as a commercial proposition, and not dictated in either direction by mere appeals to prejudice and precedent on the one hand, or to novelty and social rivalry on the other.

On the other hand it would be a mistake to give the impression that of two methods of performing a given household duty the one which costs the least is necessarily the best. Even in business the immediate cost is not the only factor considered. Every broad-gauge business man takes a wider and longer view, and the same is even more necessary in the home. The essential thing is to compare costs, and then balance any advantage one method may possess over the other in this respect against its disadvantages in other respects; such as convenience, leisure, health, character formation, and social duties. There are enthusiasts who preach the gospel of the electric home. All artificial lighting is to be done electrically. The ovens, grills, toasters, milk warmers, and other cooking appliances are all to be electrically heated. Radiators are to heat the rooms and electrical hot-water heaters to serve the lavatory, bathroom, and all general domestic purposes. The washing machine and the mangle are to be coupled to

motors, and an electric flat iron operate upon the linen, blouses, and the like. Other electric motors are to drive boot cleaners, plate washers, silver cleaners, vacuum carpet cleaners, rotary floor scrubbers, and window polishers. There are also a few miscellaneous things such as bells, cigar lighters, and clock regulators, which come within the definition of electrical apparatus, whilst a few enthusiasts urge the claims of an electrolyser for ensuring white linen and disinfected clothes in the wash, an ozoniser for purifying the water and converting a town house into a seaside summer-house, and even one or more electric lifts. No doubt a house properly equipped on the above lines could be made very comfortable for the ladies of the household, but the master would probably complain that it lacked one thing—an electrical device for earning money.

Whatever the future may have in store the complete electrical home is outside the range of practical politics at present. "First walk and then leap" is a useful guide, and each separate electrical proposal must be treated as a problem by itself and not as something inextricably bound up with an accepted social or domestic policy. Electric lighting is the first claimant for admission to the home, and it is now such an old applicant and so thoroughly established in many cases that it is perhaps hardly necessary to deal with it at length. It is, indeed, difficult to compare it closely with its principal rival, incandescent gas. It is true that there are instruments for measuring illumination, but not many of us possess them or could properly compare two illuminations differently distributed. The first test the householder makes is the size of his lighting bill, and in general it seems to work out that gas scores here, although naturally gas and current prices affect the result. On the other hand, electricity preserves the ceilings and decorations, a solid commercial advantage, which it is not easy to assess. Convenience is another advantage which counts in something like the inverse ratio of one's income. The result is that poor people and those who study economy generally prefer gas, whilst others and those who take what is offered them without consideration use electricity.

When the electric heating of rooms comes up for discussion a more considered attitude tends to show itself. Accurate comparisons are still difficult to make, but certain facts are indisputable, and certain others admitted with some qualification. Thus, electric energy is produced indirectly by the combustion of coal, and in a first-class electric generating station each unit of electricity involves the burning of 3lbs. of coal, so that the efficiency considered merely as a heat problem is about 8·5 per cent. This takes no account of losses in transmission or the fact that fuel cost is only a portion, usually between a quarter and one-sixth, of the charge to the consumer for electric power for heating purposes. Hence the equivalent commercial or cost efficiency of electrical heat up to but not including the radiator is about 1·5 per cent., with electricity at 1d. a unit. Another way of looking at the question is as follows. With fair steam coal at 10s. a ton 1d. will buy about 250,000 B.Th.U., but one unit of electricity is equivalent to 3,410 B.Th.U. only, so that if charged for at 1d. a unit the efficiency of transmission from the coal pile to the consumer's meter is only 1·36 per cent. The efficiency of an ordinary coal fire in an open grate is not easily determined. Some electrical enthusiasts put it as low as 2 per cent., but others admit 10 per cent., and one authority stated that his experiments showed an efficiency of about 14 per cent. The efficiency of an electric radiator is from one point of view 100 per cent., but a strict comparison between two different methods of heating is difficult to make because the conditions are not alike. Thus the fire warms by radiation only, but the room is cooled by the continuous influx of cold air. The electric radiator warms partly by radiation, like the fire, and partly by convection currents. These latter are also active coolers of a room where there are unprotected windows, but on the other hand there is not the same influx of cold air from outside that there is with either the coal or gas fire. Taking the average efficiency of the coal fire at 12 per cent., and of the electric radiator at 100 per cent., the ratio of their efficiencies is about 8 to 1 in favour of coal. This, of course, is only the thermal efficiency. If house coal costs 20s. a ton as against 10s. for steam coal, the ratio is reduced to 4 to 1. The balance is thus heavily in favour of coal. On the other hand, an electric radiator, if not so companionable as an open coal fire, is much cleaner and more convenient. Where the housewife does all her own work cleanliness and convenience have often a very real value, but in many small houses where social ideals demand a servant the combined domestic forces are not so overworked that convenience at least has any appreciable commercial value.

From the radiator one passes naturally to the water heater. Large quantities of hot water are a necessity. The ordinary house obtains its supply in the form of a by-product of the kitchen fire, and any form of electric hot-water heater is hopelessly beaten. On the other hand, it sometimes happens that an independent heater is necessary. A coal-fired heater would probably have an efficiency of 40 or 50 per cent., and cost only about a tenth as much as its electric rival, allowing something for losses at starting and stopping. Gas would certainly prove a more serious rival. However, water-heating is being rather left alone by the electric supply engineer, who prefers to devote his attention to advocating electric cooking. Cooking is largely a matter of heating, and the electric cooker suffers in this respect very much like the radiator and water heater. Cooking is not, however, wholly a matter of the quantity of heat. Flexibility, constancy of conditions, and convenience are very important, and these factors have already made the gas-cooker a strong rival of the coal fire. The electrical engineer claims that the electric grill, toaster, and oven possess all these advantages of the gas cooker, but in a greater degree. Some improvement may be conceded. The electricians have, however, discovered a claim which makes the others look pale. Meat, and perhaps other things, contains a good deal of water. If the first process of cooking is that of browning the meat this water is largely retained and the loss of weight much reduced. The electrical advocates argue that this retained water is just so much food. No doubt it has some palatable value, and even a digestive value, but in the long run it can hardly perform the functions of a food. The electrical cooker deserves the thanks of its rivals for raising this question, for if radiant heat is so much better than hot air for cooking there is no doubt that the gas cooker at least will supply it. In this, as in so many other instances, competition is a powerful agency of invention and improvement. The campaign of the electrical engineers also shows how important considerations of cleanliness and convenience are, and rivals will do well to learn that, whilst the home must inevitably stand on an economic basis, yet other considerations are important and must not be neglected.

ELECTRIC PROPULSION OF THE U.S. COLLIER "JUPITER."

SOME interesting details of the equipment of the U.S. collier "Jupiter," which is the first instance of electric ship propulsion on a large scale, are given in the August issue of the "Electrical World." The generating unit consists of a 6-stage Curtis turbine connected to a bipolar alternator, the speed of this unit at 14 knots being about 2,000 revs. per minute, and the voltage about 2,200. This generating unit delivers its output to two motors, one mounted directly upon each propeller shaft. These motors have 36 poles, and therefore the ratio of synchronous speed reduction is 18 to 1, the propellers at 14 knots being designed to operate at 110 revs. per minute. In addition to this apparatus there is a switchboard equipment which embraces oil switches for connecting the motors for either direction of rotation, and instruments which show and record the electric power delivered to the motors. There are also two water-cooled resistance devices, which are placed in circuit with the revolving elements of the motors during the process of reversing. Connections for the insertion of these resistances are made by sliders on the motor shafts, operated by levers attached to the motor frames. The generating unit and motors are self-lubricating and self-ventilating. Sheet-metal ducts will be connected to their air outlets in such a manner that the heated air will be led to the suction of the fire-room blowers, so that it will not be released in the engine room.

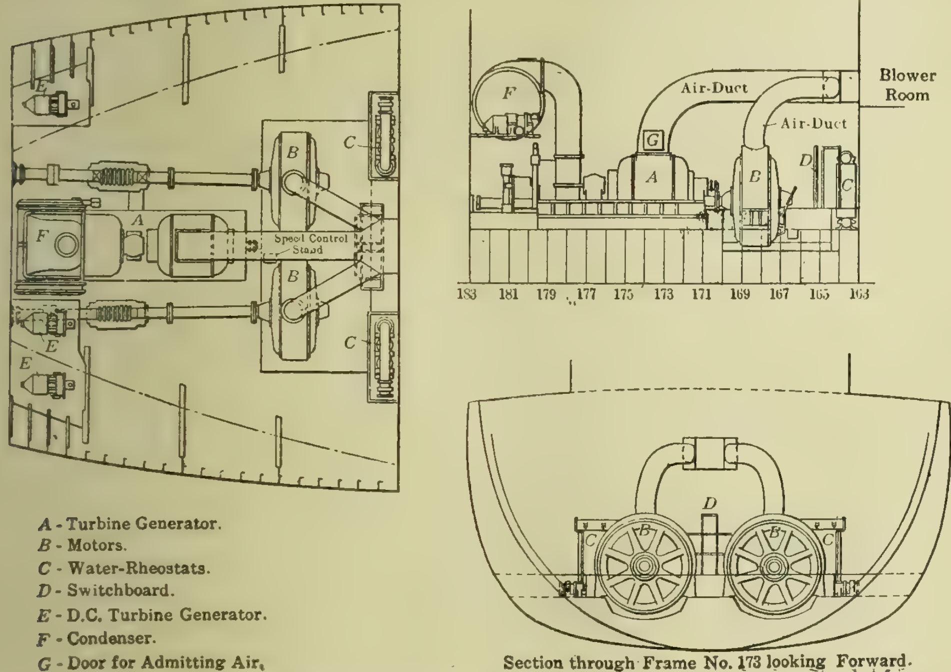


FIG. 1.—GENERAL ARRANGEMENT OF EQUIPMENT ON U.S. COLLIER "JUPITER."

Since in such an equipment it is only necessary to generate enough energy for the actual driving of the ship, it is possible so to design the equipment that the maximum power which can be delivered by the generator is not greatly in excess of the normal requirements, and this fact practically overcomes the possibility of destructive trouble through wrong connections. It has, however, been thought desirable to arrange interlocks in such a manner that wrong connections cannot be made, the conditions being such that these interlocks involve no complication or uncertainty. Provision is thus made by which the go-ahead switch and the reversing switch cannot be closed at the same time and by which neither switch can be closed unless the resistance is in circuit with the motor secondary. For the levers which throw the resistances in and out of circuit magnetic locks are provided which in turn are energised from the field circuit of the generator. These locks prevent the movement of the levers until the generator has lost its field magnetism, and thus prevent any possibility of burning of contacts through movements at the wrong time or in an improper manner.

The speed of the motors in this vessel will be changed by variations in the speed of the generating unit, the ratio of speed reduction remaining fixed. The changes of speed, however, are not made by throttling, as is usual with ship turbines. The turbine is equipped with a governor of novel construction, which is so arranged that it is capable of automatically holding the speed at any point from about 5 knots up to the maximum. The setting of this governor is accomplished by the movement of a fulcrum which is controlled from a point near the switchboard and operating levers. Thus the operating engineer, without changing his position, can run the vessel at any desired speed ahead or astern, can stop and start, and from his instruments can see the speed and amount of power delivered to each propeller. When the apparatus is installed in the ship arrangements will also be made by which in the same position he can open and close the main throttle valve by hand or trip it so that it closes instantly. The generating unit is also equipped with a simple automatic device entirely separate from the governor which trips the main throttle in case the speed of turbine exceeds a certain predetermined limit.

The propulsion methods used on this ship constitute the simplest known form of electric power transmission. Apparatus of similar character is used for a great variety of purposes on shore under conditions far more complicated and difficult, and yet with an immunity from trouble which is practically complete. No insulation difficulties, with the voltages here used, are anticipated. The equipment itself is particularly rugged and represents no departures from long-established practice. The switching apparatus is of an entirely reliable standard type, can be easily replaced or repaired, and if it were all removed the ship could easily be operated with temporary connections.

The turbine is so designed that all of its parts are accessible and replaceable, and extra parts will be carried on the vessel, so that it seems impossible that the machine will be subject to any serious interruption of service. While it is normally controlled by the governor as described, it is in no way dependent upon the governor, since by a simple disconnection it can be operated by the throttle from a point near the switchboard and motor levers. The turbine has six separate stages, and in the event of loss of blades in one or more of these stages it could quickly be arranged to operate on the remaining stages without any renewals. Any one stage of the turbine would propel the ship above half speed.

The whole apparatus was recently set up in the manufacturer's shops for a test, the turbine being connected to a

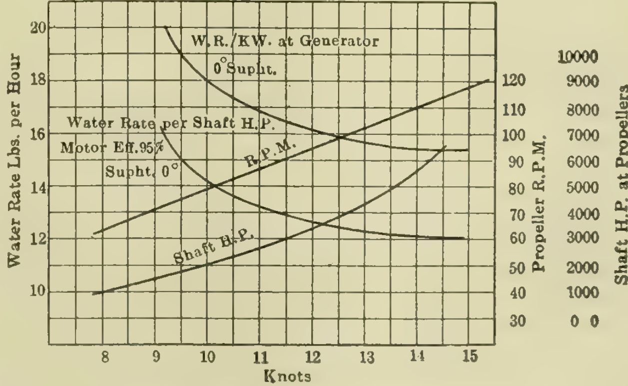


FIG. 2.—TEST CURVES OF GENERATING UNIT.

condenser and one motor being installed in the same position which it will occupy on board ship with relation to the switchboard and controlling mechanism. The other motor was arranged as a generator and coupled to the first motor so that it afforded a load. Using this generating motor as a load, the conditions of service were approximated, although they were actually more difficult than the driving of a propeller, since the load falls off only slightly with diminutions of speed unless the exciting current is reduced. With the

apparatus so installed, the processes of starting, stopping, changing speed and reversal can be accomplished very much as they would be on board ship and the time and difficulty involved can be correctly judged. The motor can be operated at its full load or any desired proportion of this load and at any desired speed, the control being accomplished by mechanical connection to the governing mechanism of the turbine, substantially the same as on shipboard.

This arrangement afforded means of experimenting with the operation, but did not afford means of testing the water rates, since only one motor could be loaded. The water rates of the generating unit have been tested under all loads and conditions by delivering its power to a water rheostat in the usual manner, and the record of these tests is shown by the accompanying curve sheet in Fig. 2. In these tests the effects of speed, voltage, vacuum and superheat were all thoroughly investigated, and a series of tests was run under almost exactly the conditions of load, speed, and voltage which will be characteristic of the ship's operation. The tests were made under almost the precise conditions of steam pressure and vacuum specified for the ship.

In the interval since the turbine for this vessel was designed new developments have been made which indicate that certain changes of design would accomplish a material improvement in the water rates shown by the tests above-mentioned. Inasmuch as it is desired to make this installation representative of the best practice, it is proposed to rebuild the turbine if the Government will allow the necessary time The new data indicate that by such rebuilding the water rate at 14 knots will be reduced from 12lbs. per shaft horse-power hour to about 11·25lbs. per shaft horse-power hour. The entire equipment is being furnished by the General Electric Company.

THE RELATION OF THE BRICK ARCH TO LOCOMOTIVE OPERATION.*

BY JOHN P. NEFF.

Because of the tremendous activity of combustion on the grate of a modern locomotive an infinitesimal time is available for the combustion of the gases given out by the coal. These gases move with great velocity and the distance through which they must pass while burning is extremely short—shorter than in any other well-known type of steam boiler, and yet the activity of combustion is greater than in any other type. These gases must burn before they reach the tubes. The tubes chill the gases and extinguish the flame. Therefore the gases must burn in the firebox if they burn at all. The purpose of the firebrick arch is to form a baffle wall in the firebox, compelling the flame to double over it, thus increasing the length of the flame. In doubling over the wall of incandescent firebrick the gases from the coal are compelled to mix with the air coming through the grate, causing complete combustion of the gases and increasing the temperature of the fire. Furthermore, it drives this hotter flame to the back and crown sheets, compelling the flame to impinge against the entire surface of the firebox. It compels every pound of coal to give up more heat. This, in brief, is the theory of the arch.

As the maximum of heat means a maximum of water evaporated, it is the function of the arch to supply a maximum of steam from the coal. With all modern improvements in the locomotive, such as valve gears for improving the distribution of steam, and superheater for improving the condition of operation of the cylinders, large boilers to increase the amount of water evaporated, we still fall back upon the firebox and upon the fire to extort the necessary amount of heat from the coal. For years arches have contributed to better performance of fireboxes, but it was not until the demand for maximum capacity was felt that the present vital necessity for the arch was finally realised. Because the arch produces more heat from the coal it is an important part of the foundation for the effectiveness of other improvements which have been made in recent years in the locomotive.

With the realisation of the possibilities of the arch in this direction came improvements in the arch itself, in the material employed, in the structure and method of support, and in the form of the brick which have added to the other good features of the arch, that of convenience in application, low cost of maintenance, and facility for inspecting the firebox sheets and conducting necessary repairs. The arch to-day enables the fireman "to shovel more horse-power through the fire door." Recent improvements in the arch render it possible to secure this advantage and increase the capacity of the fireman, with a minimum of maintenance cost and a maximum of convenience at locomotive terminals.

The brick arch is like the superheater in one respect—the harder you drive your boiler, the better showing it makes. This fact largely accounts for the revival of the brick arch. When the progress of locomotive design reached that point where clearances and weights became the limiting features, it then became necessary to crowd greater boiler capacity into the limits already reached. To meet the still crying need of greater hauling capacity, boilers had to be forced harder than ever before, and very soon the fireman's capacity became the limiting feature. Still we had with us the need for greater sustained boiler power in order that trains with their increasing tonnage might have their schedules maintained or improved. Then the question became, "What can be done to get more hauling power for a given amount of coal consumed?"

Valve motion experts have long been working on steam distribution to get the best possible results out of the cylinders, but in their work they have had to take the steam just as it came from the boiler, and it would appear that they have reached the point where more power can be had only by calling for more steam or for steam of better quality. The superheater experts have done a great deal by providing the best quality of steam, but back of the steam distribution proposition and back of the superheater work we come to the foundation, the trick of getting heat units transferred from the coal to the steam with the least possible loss. Anyone riding and observing a modern locomotive being forced to its maximum must admit that the firebox is the real business end of the power plant.

In order that the superheater may best perform its function it is desirable that the duties of the firebox be so performed that the hottest, cleanest gases are supplied to the flues, so that the proper degree of superheat may be attained with the least possible sacrifice of evaporating surface. That is why you see the superheater people so favourable to the use of brick arches. The brick arch really performs a double duty in this connection —first, it increases the firebox temperature for any given condition, due to the more nearly perfect combustion brought about by the mixing effect on the gases and air and the lengthening of time for combustion; and, second, the arch, by virtue of its position, forces every part of the firebox heating surface to do its full duty in the matter of evaporation.

That substantially higher temperatures are produced by the arch is proved by many conclusive tests. The arch must necessarily show a much more even distribution of temperature in the firebox. A modern hand-fired locomotive working well up to the physical capacity of its fireman, has its fire door open at least 50 per cent. of the time. Without the baffling effect of the arch, sudden and extreme fluctuations of temperature over part of the flue sheet must result. Locomotives with well designed arches are known to give 30 to 50 per cent. less flue trouble than the same engines without arches.

A very elaborate report was presented at the recent convention of the Master Boiler Makers' Association on the subject of "Advantages and Disadvantages of the Brick Arch and Arch Tubes in Locomotive Fireboxes." In this report some 50 members contribute statements of conditions and facts as they have been found to exist on 30 of the prominent roads in this country using brick arches. A composite of the 50 reports reads as follows: Average coal saving due to brick arch, 11·9 per cent.; average smoke abatement, 40 per cent.; average reduction in frequency of caulking flues, 40 per cent.; attitude of engineers and firemen, favourable. A majority of the reports from the various roads shows that the arch is effective in improving steaming qualities and reducing engine failures. There were many other features reported on by the boilermakers, but the above points are the ones that bear directly on our subject which has to do with the locomotive operation.

* Abstract of paper read before the Railway Club of Pittsburg.

Personal.— The Home Secretary has appointed Mr. Arthur L. Flint to be a Junior Inspector of Mines under the Coal Mines Regulation Acts, and has directed him to act also as an Inspector for the purposes of the Metalliferous Mines Regulation Acts, and of the Quarries Act, and has further appointed him to be an Inspector of Factories and Workshops.

NEW DEVELOPMENTS IN STEAM TURBINE ENGINEERING.*

BY EDWIN D. DREYFUS.

(*Continued from page 241*).

Application to Power-house Auxiliaries. —In the development of the turbine, attention was first paid to the building of main units where it was perceived that the reciprocating engine had its limitations. Evidently almost as many factors commend the turbine for auxiliary drive as for the large prime mover. They are, in brief, uniform rotation, absence of vibration and shock, elimination of oil in the exhaust, reduced floor space, and decreased maintenance and investment charges. Consequently turbines are now being successfully used to drive: (1) Exciter sets, (2) Condenser air and circulating or evacuating pumps, (3) Centrifugal boiler feed pumps, (4) Blowers for mechanical draught.

Direct-current Turbine Generator Sets for Excitation Purposes.—These sets naturally followed in the wake of the large alternator, in spite of the fact that the first turbine unit generated direct current. The commutator problem was the most difficult to overcome in direct current work, and therefore this type has proceeded slowly. While this feature has been completely solved in all small sizes, the use of the large direct-coupled generating unit is still open to debate.

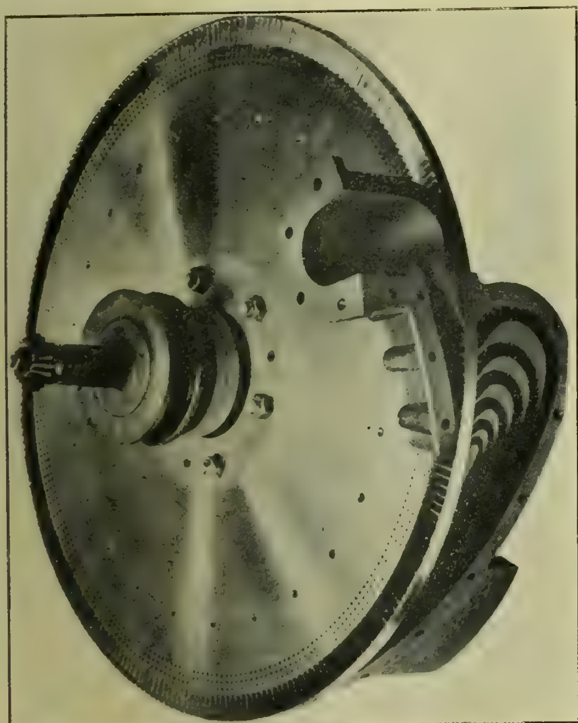


Fig. 8.—Turbine with Nozzle Block and Reversing Chamber.

There are various types of small turbines, but they are in practically every case of the impulse class, since the reaction type does not lend itself commercially for small powers. Simplicity being the byword in the design of small turbines, the axial re-entry principle has many merits, the main feature being that a single-bladed wheel only is required, multiple pressure and velocity drop being attained through re-entry nozzles and passages. The construction has been in general use for some time, and hence is familiar to power-plant operators.

In this arrangement, relative changes in the parts for varying operating conditions is carried out in a most simple manner, either by increasing or decreasing the nozzle and reversing chamber areas and angles according to requirements, one set of castings thus being applicable to a wide variation. This is extremely important in small sizes on account of the greater possible range of working pressures, and such characteristics as noted are necessary in order that they may be properly taken care of. The nozzle block and reversing chambers in Fig. 8 (a detail of a 50 kw. exciter set) exhibit the re-entry principle.

Although centrifugal pumps have been used since about 1880, or possibly a little earlier, for working against high heads, they have come into vogue in the boiler plant only within the last five years. Centrifugal boiler feeders might be conveniently operated by electric motors, but the usual demand for exhaust steam for feed-water heating requires that they be steam driven, hence the direct coupled turbine unit.

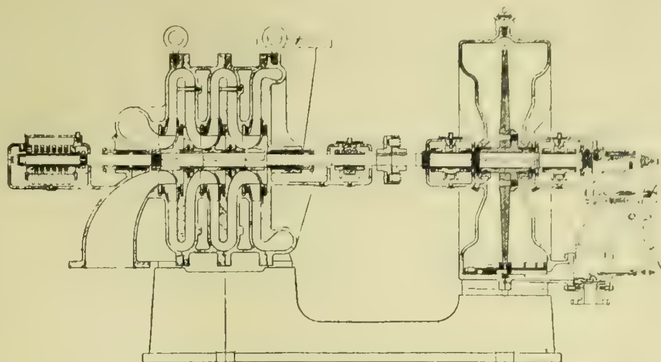


Fig. 9.—Turbine and Three-stage Centrifugal Pump.

Owing to the relation of capacity, pressure, and impeller diameter, the centrifugal pump is not suited to small capacities and high head, and this design may therefore be employed only in plants exceeding 2,500 h.p. Ordinarily a stage is provided to create 50lbs. to 70lbs. pressure. Consequently for in the neighbourhood of 175lbs. gauge pressure, a three-stage unit is required. A sectional exhibit of a three-stage pump and the driving turbine is shown in Fig. 9, which displays fundamental simplicity in contrast with the multi-deck valve plunger pump. Difficulty with valve packing and of close governing has been obviated in this type. There is no definite way of comparing efficiencies, but it is reasonable to assert that where the centrifugal pump is operated beyond two-thirds of its rated load, it should excel in efficiency. Actual experience with the two types of boiler feeders should be a criterion by which to correctly judge them. One operator who installed this type of apparatus in 1906, has expended practically nothing so far for repairs.

A turbine-driven vacuum air pump evidently involves the most radical departure from preceding power-plant practice. An air pump employing water jets or sheets to eject or evacuate the air from the condenser was invented by M. LeBlanc, and is capable of being operated at the high speeds suitable for direct connection to small turbines. The principle is simple. An impeller, *B*, Fig. 10, with shallow blades, imparts a high velocity to sheets of water collected in passing the nozzle *A*, and which, ejected into the air passage, entraps layers of air. By means of a diffuser its velocity is transformed into pressure, forcing the mixture of air and water out against atmospheric pressure, or a somewhat greater head, as the case may demand. The advantages of this type are quite plain. We again evade the necessity

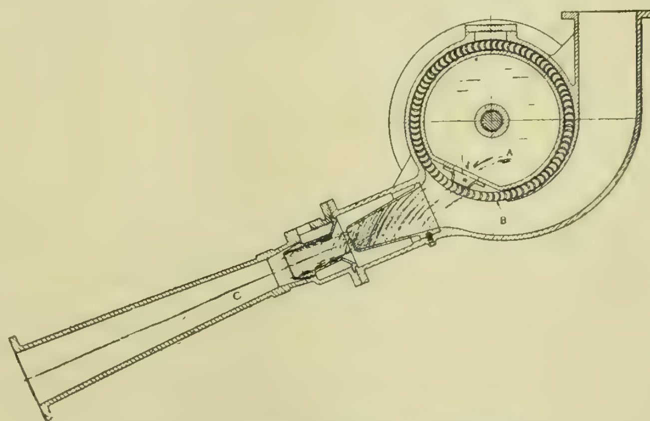


Fig. 10.—LeBlanc Air Pump for Condenser.

of closely fitted parts and rubbing surfaces, requiring lubrication and frequent adjustment and the separation of the oil from the exhaust steam where used in connection with an open heater. As there are no reversals in operation, the harmful effect of clearances in the reciprocating air pump is avoided and a low absolute back pressure may be maintained. The operating characteristics of the LeBlanc and

* Paper presented before the Western Society of Engineers, March 4th, 1912.

the reciprocating air pumps are divergent, which may be best illustrated in the manner shown in Fig 11, determined from actual test. Above the line *AA* the LeBlanc pump would always be superior to the reciprocating pump, even if its power consumption were in excess. If the latter were identical in the two cases, the LeBlanc pump would always be more efficient when working the region above *BB*, and inferior below *BB*. The conditions for high vacuum service

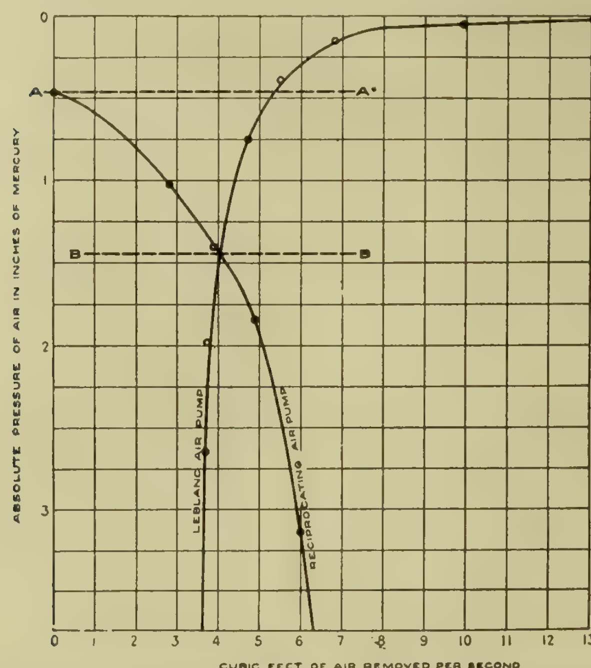


Fig. 11.—Curves showing Comparison of Air Removed by Reciprocating Air Pump and LeBlanc Air Pump.

are generally such that the air tensions to be maintained are above *BB*, so that the question of power consumption is therefore not the final criterion. The question of air tension maintained must also be considered. Where condensers are used with steam turbines, the ½in. lower air tension which would be secured with the LeBlanc pump would result in a decrease of 2 per cent. or more in the steam consumption of the turbine. This (considered together with the use of the auxiliary exhaust in the feed-water heater) may closely compensate for the whole power consumption of the condenser.

The general conclusion to be drawn from both theory and practice is that for high vacuum performances, the LeBlanc pump, on account of the characteristics shown in Fig. 11, in nearly all cases will show a net saving in plant economy, either by giving a better vacuum for the same power as would be required by a reciprocating pump, or by the reduced air tension in the condenser, making it unnecessary to circulate as much cooling water to maintain the same vacuum. As an illustration, it is of interest to review the facts brought out in a recent installation of a surface condenser plant equipped with a LeBlanc air pump. In this particular plant, high vacuum was desirable as the condensers are to be used in conjunction with steam turbines. The reciprocating air pumps were giving fairly good results, but were not quite large enough, and it was decided to install greater pumping capacity, either by putting on larger air cylinders, purchasing a new reciprocating pump, or installing a LeBlanc air pump. The LeBlanc air pump for this work, while requiring 40 per cent. more power, had a capacity substantially the same as the reciprocating pump for a vacuum of approximately 28in. of mercury, but with 29in. of vacuum, its volumetric capacity was practically three times that of the reciprocating pump, characteristically brought out in Fig. 11. The net result was that the LeBlanc pump enabled the maintenance of half an inch better vacuum under winter conditions, so that the bettering of the economy of the prime mover far offsets the slightly increased power consumption of the LeBlanc air pump over that required by the reciprocating pump.

The unit shown in Fig. 12 has a hot-well pump attached, and would be employed in surface condenser work, or, without the hot-well pump, for barometric condensers. Heretofore the LeBlanc air pump has been more commonly employed with low-level jet condensers, Fig. 13, showing an improved type specially designed to embody this principle. This equipment may be neatly tucked away beneath the turbine, and thereby occupies no space outside of the boundary of the turbine proper, as the layout appended shows.

Mechanical Draught.—In the past mechanical draught has not met with universal favour for boiler plant operation. A new condition is rapidly coming to the fore, manifesting itself in the nature of forcing boilers to double and even more than treble their accustomed ratings to accommodate peak loads and still maintain good efficiencies in the boiler house during the hours of light load on the plant. High rates of driving boilers require forced draught. In the main, large "paddle wheel" fans driven by small, high-speed engines have been used in this service. The same trend which has influenced the replacement of the reciprocating engine in other classes of auxiliary work has already been observed in blower operations. On top of the other common advantages of the turbine, which have been noted before, the shaking and racking of the blower casing, ducts, and supports are removed. The blower in its old form proves itself deficient for connection with the turbine in the present state of the art. A shallow blade construction, with guide vanes for low pressure (as shown in the upper part of Fig. 14), propels the air with the least losses and power consumption. The vertical type is exhibited to indicate the flexibility of the turbine application. This specific design has been prepared for use aboard United States torpedo-boat destroyers, for forcing air under pressure into the boiler room. A down-draught duct from the deck connects with the blower intake, and the discharge is made directly into the room. The turbine in this position is most accessible, and it is also evident that this arrangement requires but a minimum of duct lengths and bends. In a similar way some special problems in land practice may arise and be met by a corresponding design, although with the latitude permitted in power plants, a more standard construction will be unquestionably adopted.

Extended Utility of the Turbine by Perfection of the Large Reduction Gear. — Use of reduction gears in turbine work dates back to the introduction of the de Laval turbine in 1886. These, however, were of small size and of the solid-bearing type. Where the power transmitted becomes of any magnitude, with dimensions correspondingly increased, the minute errors in gear cutting may greatly magnify or intensify the unit pressures on the teeth with excessive wear or fracture resulting. A compensating element must then necessarily be provided. The development of the Westinghouse reduction gear, which was instituted in 1904, has had for its essential feature the carrying of the pinion in a floating frame, which prevents the concentration of abnormal pressures at any one point by automatic readjustment of its

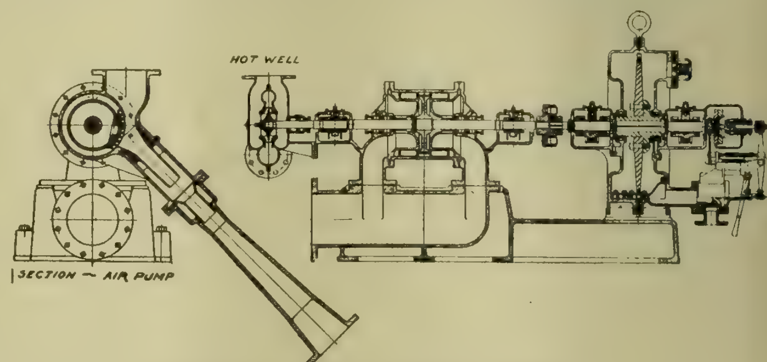


Fig. 12.—Hot Well Pump-condensing Apparatus.

position. This gear has already been described at great length in preceding articles, and its detail, therefore, will only be treated generally in this paper.

The important structural and operating features may be understood from the following summary: (1) Self-aligning, hydraulically-supported floating frame for pinion; (2) pinion frame pivoted at centre bearing on fulcrum, permitting small oscillations; (3) hydraulic pressure in cylinders a measure of the power transmitted; (4) spray lubrication for gear teeth; (5) divided helical gears cut right and left hand,

neutralising end thrust; (6) teeth of gear cut in special steel rim mounted on spindle; (7) depth of mesh easily regulated by hand adjustment; (8) flexible driving shaft extending through hollow pinion; (9) flexible disc coupling to turbine.

A detail section through the pinion and floating frame is given in Fig. 15. The most interesting feature of the gear lies in the means provided for preserving line contact of the teeth and the automatic adjustment of any slight wear which

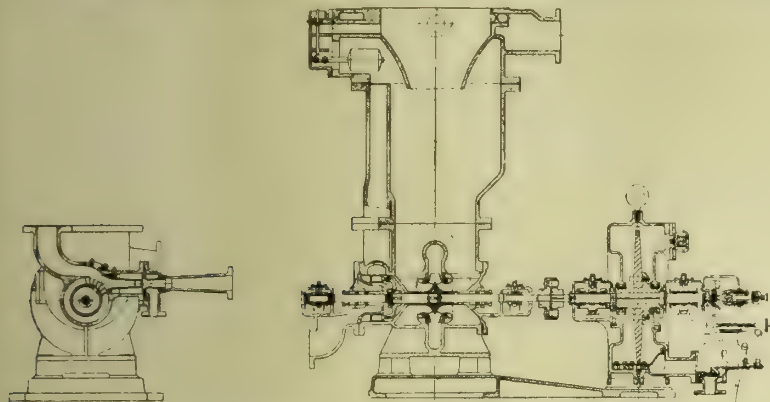


FIG. 13.—LEBLANC PUMP WITH LOW LEVEL JET CONDENSER.

may occur. This is done by carrying the pinion shaft in a three-bearing frame, supported by hydraulic pressure beneath each bearing. The frame itself is rigid and is split horizontally to receive the pinion. On the lower side of the pinion frame, and cast integral with it, are the three cylinders above referred to, and into which project short stationary pistons resting upon planed pads of a girder cast into the gear frame. Oil pressure is led to the space over the upper surface of the pistons through passages cored out in the pinion frame, and which communicate with all three cylinders, establishing uniform pressure. Hence any inequality of tooth-bearing pressure would be conveyed to the pistons and thus instantly neutralised. The prominent use of the geared turbine will be in connection with: (1) Large direct-current generators; (2) large centrifugal pumps; (3) large slow-speed propellers; (4) rolling mill trains.

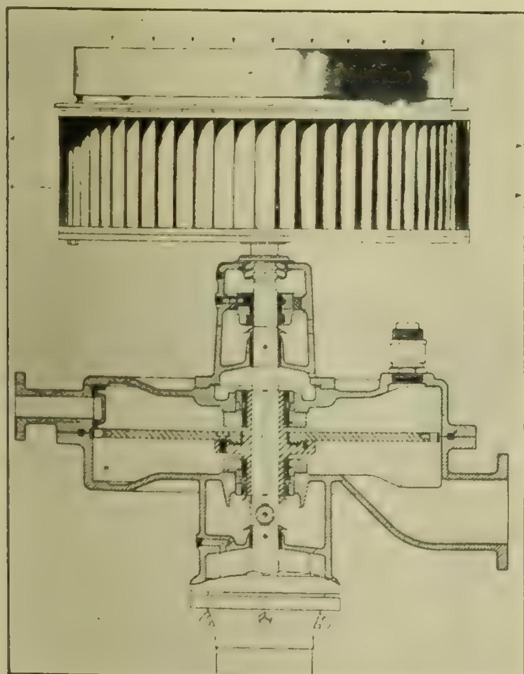


FIG. 14.—TURBINE AND FAN FOR FORCED DRAUGHT.

Direct-current Service.—While there have been many large direct-coupled direct-current generators built, especially abroad, such skilful attendance is necessary that they cannot be so far termed a complete mechanical success. There is no room for argument that the best efficiency is sacrificed by a compromise in the design of the two elements, and this plainly opens up a large field for the geared unit. Contrary to ordinary expectation the length of the complete direct-current unit is not increased in placing the gearing between turbine and generator, and principally for two reasons: First, the length of the high-speed turbine is much less than a lower revolution machine of equal capacity; and second, a high-speed, continuous-current generator for direct-coupled units requires a long, slender commutator. Direct-coupled geared units as large as 1,000 kw. are now successfully operating in railway service with a turbine speed of 3,600 revs. per minute.

Centrifugal Pumping.—Undoubtedly further use will now be made of the large turbine-driven centrifugal pumps by reason of advances in economy resulting from the introduction of the reduction gear. Direct drive has, however, been applied to this class of service, an example of which may be found in a municipal pumping plant in Canada, where two 1,125 h.p. 1,500 revs. per minute turbines were installed in 1906. Another installation of this kind was made comprising a 1,800 revs. per minute, 6,506 h.p. turbine and centrifugal pump. The latter did not experience a very large measure of success owing to the high speed employed, and accordingly has since been removed, a generator being substituted for the pump and an electrical load supplied.

An interesting installation of a pumping unit having a reduction gear interposed, has been in operation for some time in an eastern steel mill. The pump is driven by a 700 h.p, low-pressure turbine, as this application was the most profitable use to which the surplus exhaust steam could be turned.

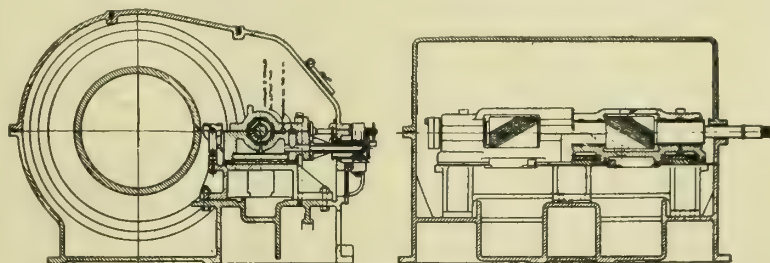


FIG. 15.—ARRANGEMENT WITH REDUCING GEAR.

A reciprocating pump, under the existing conditions, would obviously have worked in very poorly. Well-designed triple-expansion engines ordinarily have a duty of 150,000,000 ft.-lbs.* per 1,000lbs. of steam (150lbs. dry-saturated), while the direct-coupled turbine and pump may show only about half as good a performance as that of the reciprocating type.

The 750 h.p. low-pressure outfit, when operating with 27in. vacuum, has been guaranteed to develop a duty of 52,074,000 ft.-lbs. per 1,000 lbs. of dry-saturated steam supplied at a pressure of 15lbs. absolute. The pump is designed for an efficiency of 75 per cent., and the gear is included at 97 per cent., a water rate of 28·6lbs. per brake horse-power having been used in determining the above duty. With a complete expansion turbine driving through a gear, the combination would attain a result of about 110,000,000 ft.-lbs., and probably 120,000,000, or better, with a greater pump efficiency, which we believe possible—an interesting approach to the triple-expansion engine above noted. In cases where the pumping equipment is to be operated intermittently, the commercial economy of the geared turbine set should become superior, owing to its lower first cost and repair charges, considering its inherent simplicity as compared with, for instance, the vast number of small deck valves employed on the reciprocating unit.

(To be continued.)

Light Railway.—The Board of Trade have recently confirmed the Halesowen Light Railways (Extensions, &c.) Order, 1912, reviving the powers granted by the Halesowen Light Railway Orders, 1901 to 1909, and extending the period limited by those Orders for the completion of part of the light railways and works thereby authorised, and authorising the construction of additional light railways in the urban district of Lye and Wollescote, and in the urban district of Rowley Regis, in extension of the said light railways authorised by the said Orders of 1901 to 1909, and for other purposes.

* Highest record with superheat, reheating and steam jacketing, 184,476,200 ft.-lbs., Philadelphia pumping station.

VALVELESS STEAM AND GAS ENGINES.

A RECENT patent granted to Messrs. Mather & Platt, Ltd., and Mr. A. E. L. Chorlton, Salford Ironworks, Manchester, relates to fluid pressure engines (including internal-combustion engines) of the valveless type, in which two double-acting pistons connected to the same crank shaft work in cylinders placed side by side and communicating with each other by connecting chambers at each end. In an engine of this type one piston serves as an admission valve for the

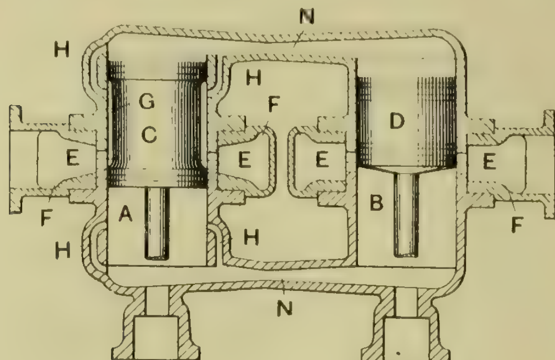


FIG. 1.—VALVELESS STEAM ENGINE.

charge and the other as an exhaust valve. In the design under notice the double-acting piston serving for admission of the motive fluid is given a lead with regard to the other piston by setting the crank pin to which it is connected at an angle to the crank pin of the exhaust piston. The lead of the admission piston may be adjusted by varying the setting of the crank pins so as to obtain the best result under varying conditions. In the case of valveless steam engines the admission piston has a backward lead over the exhaust piston and is formed with a steam channel affording communication at the end of each stroke between a centrally-placed steam inlet and a by-pass in the cylinder admitting steam to the working space of both cylinders. As applied to double-acting internal-combustion engines of the 2-stroke kind the exhaust piston is set a little in advance of the admission piston, so that the exhaust port is opened shortly before the admission port and the pressure in the cylinders and the connecting chamber at either end is released before the scavenging air enters and drives out the remaining products of combustion. As the inlet port remains open after the exhaust is closed a larger charge can be introduced than would be the case without such lag in the closing of the

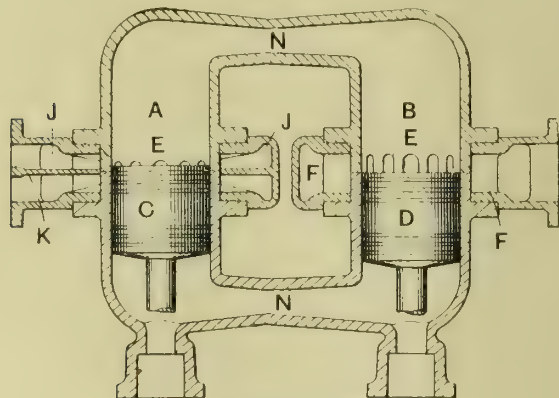
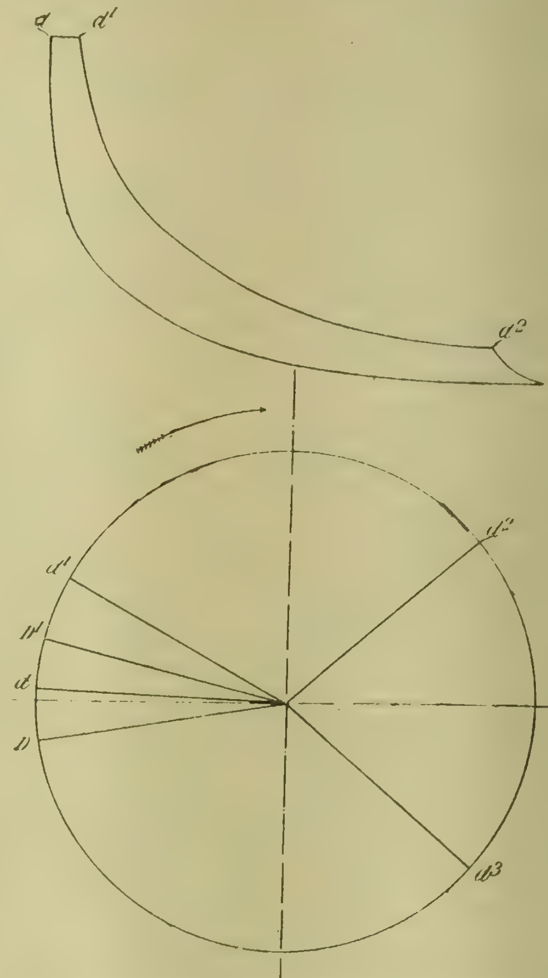


FIG. 4.—VALVELESS GAS ENGINE.

inlet port, full advantage being taken of the pressure in the inlet pipe. The difference in phase between the cranks may be such that the inlet port both opens and closes after the exhaust closes.

Fig. 1 is a vertical section of the steam engine, and Figs. 2 and 3 are respectively a typical indicator diagram (for the exhaust cylinder) and valve diagram of the steam engine. Fig. 4 is a vertical section of the internal-combustion engine showing the relative positions of the pistons at about the end of a stroke. A B are the inlet and exhaust cylinders having contracted connecting passages N of venturi type. C D are the double-acting inlet and exhaust pistons with piston rods passing through glands in the lower ends of the cylinders. The inlet and exhaust ports E are placed centrally and extend around the circumference of each cylinder, establishing communication during the required intervals between the cylinders and the annular inlet and exhaust chambers F, which are secured between cylinder flanges. The cylinders, which are of special construction, consist of two single-walled U-shaped tubes, one inverted over the other and carrying the annular inlet and exhaust boxes between their uniting flanges.

Referring to Fig. 1, the inlet piston C is of different form to the exhaust piston D, and is substantially longer. The central portion or body of the piston is reduced to form end flanges and a central annular chamber or channel G, which is open to the inlet chamber F through the ports E towards



FIGS. 2 & 3.—DIAGRAMS FROM VALVELESS STEAM ENGINE.

the end of a stroke, and establishes communication between these ports and the lower end of the by-pass H leading to the back of the piston. The illustration shows the position of the piston when steam is being admitted to the upper end of the cylinders, a by-pass H being placed at each end of the inlet cylinder. The cranks to which the pistons are connected are, as shown diagrammatically in Fig. 3, set at an angle to each other, d indicating the position of the exhaust crank and D the position of the inlet crank near the dead centre, the former crank being set in advance of the latter so that the inlet piston lags behind the exhaust piston, and the relative position of the pistons at about the end of a stroke is approximately as shown in Fig. 1.

Figs. 2 and 3 are diagrams for one end of the cylinders (Fig. 2 is drawn for the exhaust cylinder only), the points D and D_1 showing the positions of admission and cut-off in the inlet cylinder and d and d_1 in the exhaust cylinder and d_2 and d_3 the positions of opening and closing of the exhaust in the exhaust cylinder. The angle of lead given to the inlet crank may be adjustable to suit varying conditions of working. The cycle of operations is the same for both ends of the cylinders, and is clearly shown by the diagrams, Figs. 2 and 3, which are, however, to be regarded only as typical examples

subject to considerable changes in the positions both of the cranks and of the points of opening and closing of the inlet and exhaust.

In the internal-combustion engine shown in Fig. 4 the inlet and exhaust pistons C and D are similar to each other, and the exhaust piston D is set a little in advance of the inlet piston C, so that the ports E of the exhaust are uncovered before the inlet ports, and the incoming charge meets with no appreciable back pressure until the exhaust closes, which occurs shortly before the closing of the inlet, permitting a full charge under the pressure of the delivery pump to be introduced. The annular inlet chamber J may be provided with one or two partitions K to admit separate air and fuel charges, the valves of the gas and air pumps being set so that the air enters first as a scavenging charge, to be followed by the combustible mixture. As in the case of the steam engine first described, the cycle of operations is the same for both ends of the cylinders.

THERMAL PHENOMENA IN INDIA-RUBBER.*

A SERIES of experiments on the elasticity of rubber was conducted in 1843 by Joule, who states that a piece of india-rubber, softened by warmth, may be exposed to a temperature of 0° Fah. for an hour or more without losing its pliability, but that a few days' rest at a temperature considerably above the freezing point will cause it to become rigid. Joule also carried out an extended investigation on the thermal effects of stretching both vulcanised and unvulcanised rubber. The rise or fall in temperature was measured by means of a thermo-junction consisting of thin copper and iron wires. A cooling effect was first observed on extending the rubber specimen, which changed to a heating effect with larger tensions. In connection with these experiments, Joule makes the important statement that "at temperatures a few degrees higher, the reverse action with weak tensile forces did not take place, but that there was, on the contrary, a very slight heating effect." Joule also made the following statements with regard to vulcanised rubber: (1) That the quantitative effect of laying on the weights was not sensibly different from the reverse effect of removing them; and (2) that with light weights and a low temperature there was a slight cooling on the application of tensile force, which ultimately changed into a heating effect, increasing much more rapidly than the stretching weight. A theory to account for this double effect of heating and cooling has been developed by Chauveau.† The molecular changes which the rubber undergoes when in tension are divided into two classes, each of which produces its own characteristic phenomena. The two effects may be briefly described as follows:—

(1) A displacement of the position of the molecular groups relatively to their positions of equilibrium.

(2) A change in the dimensions of the inter-molecular spaces.

The first effect always produces heating, and the second sometimes heating and sometimes cooling. The net result is sometimes heating and sometimes cooling. In one condition no thermal change results at all. The displacement of the molecular groups relatively to one another, constituting a source of heating, is proportional to the total work done upon the specimen in extending it. Chauveau states that the work due to the change in the dimensions of the inter-molecular spaces is simply a function of the distance traversed by the load, assuming that the changes of volume experienced by the body are proportional to the alteration of longitudinal extension, which is practically so in the case of rubber. Consider a cubical specimen the length of whose side is x. The body is put into tension along one axis and becomes lengthened along that axis, the cross-sectional area simultaneously diminishing. Let the new length be x_1, and Poisson's ratio for this particular specimen be σ, the value of which changes with load. Then the new breadth is equal to $x - \sigma(x_1 - x)$ and the new volume becomes $x_1(x - \sigma(x_1 - x)^2)$. The ratio of this new volume to the new length comes out constant within 1 per cent. throughout the range of stretching weights used. If the thermal neutral point is known, at which neither heating not cooling results upon the application of tension, then it is possible to calculate the shape of the thermal curve for different tensions. Chauveau's hypothesis does not explain the fact that this double effect of heating and cooling is not obtained at the ordinary temperatures of the atmosphere.

* From an article by A. Schwartz and P. Kemp in "Le Caoutchouc et la Gutta-percha." Reproduced from Vol. V. of the "Journal of the Municipal School of Technology," Manchester.

† Paris l'Académie des Sciences, February, 1899.

Mechanism of Extension.—Certain molecular changes take place in rubber when it is subjected to tension. The previous history of the specimen affects the rate of extension on the application of tension. One may conjecture that two or more types of molecular agglomeration exist. The ordinary form of extension curve for a specimen of vulcanised rubber is fairly straight at its commencement. As the tension is gradually increased the rate of extension with load increases considerably, and the rubber is now in such a condition that when the stress is removed the retraction curve does not trace a path coincident with the extension curve, but forms a new curve in which the deformations are much greater for a given tension than they were for the corresponding tension on the extension curve. This behaviour can be explained on the hypothesis that the material under test consists of at least two kinds of molecular agglomerations. When subjected to small stresses each of these behaves in the same manner, causing an extension of the whole proportional to the applied stress. As the tension is gradually increased one type of molecular grouping is stressed to its limit, and consequently breaks up. The extension curve now begins to leave the straight-line formation and enter its second stage. In the second stage some of the weak molecular groups break up, whilst the stronger and more stable ones still persist in their original behaviour; the resultant extension curve being due to the combination of these two factors.

Effect of Temperature on Extension.—This question has been studied by Schmulewitsch,* who considered the resultant change of length to be influenced by two different factors, viz.: (1) The change of length due to the natural expansion or contraction of the body with rise of temperature; and (2) the expansion or contraction due to a change in the modulus of elasticity of the rubber. It has been recently shown by the authors that virgin rubber has a positive temperature coefficient, and also that the effect of raising the temperature is to render the body less extensible when subjected to tension. Thus a positive temperature coefficient of linear expansion and an increase in the modulus of elasticity represents the actual state of affairs. The effect of the temperature coefficient of linear expansion is to raise the curve parallel to itself when the temperature is raised, and the effect of the increase in the modulus of elasticity is to decrease the slope of the curve. Taking the algebraic sum of these two component effects, it is seen that the extension curves for two different temperatures cut one another, and the higher the temperature the flatter the curve (within certain limits). Following out this reasoning, it is possible to obtain a contraction on heating up the specimen if it is subjected to tensions above a certain value. The expansion curves under constant load all showed two distinct stages, these being more marked in the cases where the specimens were subjected to considerable tensions. The first stage of the curve consisted of a fairly flat portion which continued up to a certain temperature, usually between 20° C. and 30° C., at which a sudden change occurred. The curves then trended rapidly upwards until the specimen broke. It is quite possible that the discrepancy between these results and those obtained by Schmulewitsch is caused by the latter experimenter having used vulcanised rubber, whereas the authors employed spread rubber tape, or to the fact that the rubber used by Schmulewitsch may have been previously extended, whereas that employed by the authors was in a virgin state.

* Vierteljahrssch der Naturforsch. Gesell Zurich. 1866.

New Naval Airship.—A new naval airship for the British Admiralty is to be built at Barrow. For some time past the work of demolishing Airship No. 1, which was wrecked some months ago, has been proceeding. This task has been well nigh accomplished preparatory to the laying down of Airship No. 2, the design for which has been in preparation for some time past, and has now been approved. The work will be undertaken by Vickers, Ltd.

BOILER ECONOMICS AND THE USE OF HIGH GAS SPEEDS.*

BY J. T. NICOLSON.

(*Continued from page 236.*)

PART V.—RESULTS OF TRIALS BY MR. LONGRIDGE.

THE objects of the construction, running, and testing of this experimental boiler plant were as follows:—

1. To show that a greatly increased rate of evaporation per unit of heating surface could be attained by a mere increase of the gas speed.
2. That this increased evaporative power could be got without any sacrifice of evaporative or thermal efficiency.
3. To prove, by continuous working, that the narrow flues which the use of a high gas speed entails do not choke up with tar or coal dust, and do not corrode at the outlet end of the flues.
4. To show that by the use of high speed directed flow of the feed water in small bore tubes, the deposit of sediment is avoided, and that corrosion due to pitting cannot take place.
5. To verify Osborne Reynolds' law of heat transmission.

A portion of the report by Mr. Longridge is given in Appendix V.; but for convenient reference the principal results have been summarised, and are given in the annexed Table IV. The extent to which the objects aimed at in the tests were attained will now be commented upon:—

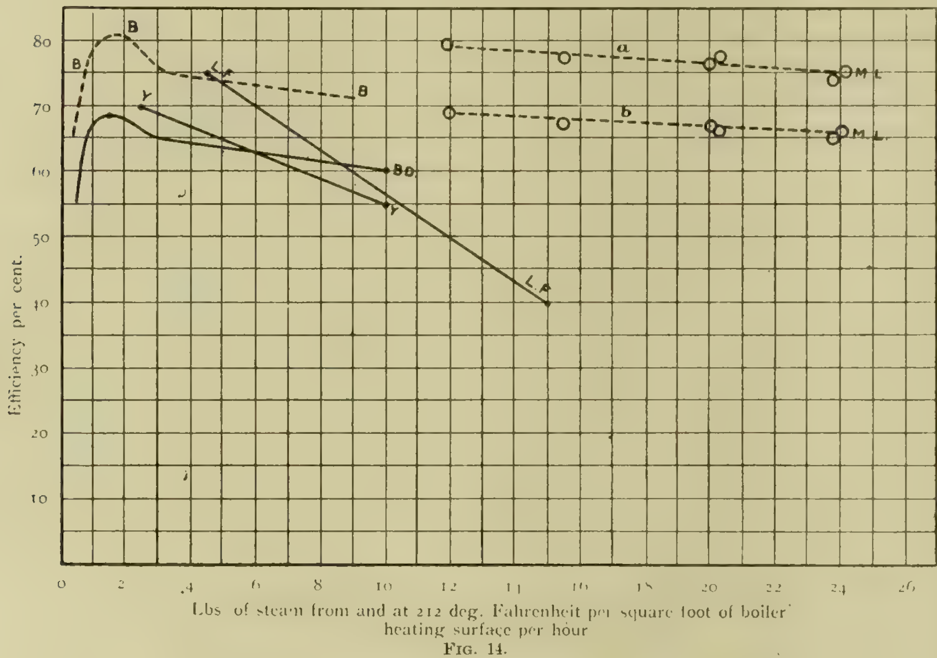


FIG. 14.

TABLE IV.

	Manvers Main (dusty). Cal. val. 13,166 Th.U.'s.			Nixon's Navig. (nuts, also dusty). Cal. val. 14,929 Th.U.'s.		
October	12	13	14	19	20	21
46 Coal burnt per square foot of grate per hour	37·8	38 0	22·8	26·4	40·8	40·7
51 Water evaporated per pound of dried coal from and at 212°.	10·542	10·370	10·780	11·993	11·413	11·610
53a Evaporation from and at 212° per square foot of boiler and evaporator surface	19·25	19·02	11·87	15·45	22·77	23·06
53 Evaporation from and at 212° per square foot of total heating surface, including economiser...	10·65	10·5	6·56	8·53	12·58	12·75
38 Thermal efficiency of boiler, per cent.	77·4	76·8	79·1	77·6	73·8	75·0
Net efficiency, deducting steam for fan, per cent....	66	66·8	68·9	69·1	64·4	66·1
Chimney loss, per cent.	—	6·7	6·7	6·4	5·4	5·8
42 Loss by incomplete combustion, per cent.	—	2	2·6	0·5	1·1	0·0
44 Loss due to coal dust blown away, radiation, &c., per cent...	—	15	11·3	13·2	16	13 3

1. Increase of rate of evaporation due to increased gas speed in experimental boiler.

This is most directly shown by collecting some of Mr. Longridge's results with others taken from ordinary practice. Thus, in Table V., line 2 (last five columns), the average gas speeds through the author's boiler have been written down, and in the next two lines the evaporations per hour per square foot of heating surface actually obtained. In line 3 these are per square foot of boiler only, in line 4 for both boiler and economiser. In the first three columns of the same table a few results of land boilers, taken from Bryan Donkin's book, are given for comparison. It will be seen that, roughly speaking, the rate of evaporation in pounds per hour per square foot of total heating surface (boiler and economiser) increases directly with the gas speed, being equal in pounds per square foot per hour to from one-eighth to one-tenth of that speed in feet per second. Thus, with a speed of 20 feet per second (common in land boilers of the Lancashire or Babcock type) the evaporation is 2lbs. or 3lbs. per square foot of total heating surface per hour, whilst with 100ft. per second the evaporation is 11lbs. or 12lbs. per square foot per hour.

2. In Table V., also, the thermal efficiencies have been entered in line 5, *i.e.*, the ratios of heat transferred to water to the whole heat in the coal. In line 6 the net efficiency of the experimental plant, as determined by Mr. Longridge, has been added. These figures allow for the steam spent upon driving the fan and circulating pump. Referring to line 5, it will be seen that the efficiencies of the high-speed boiler compare quite favourably with those of the slow-speed type, as exemplified by present-day land boilers; whilst line 6 shows that the net efficiency does not fall off nearly so much with the high-speed boiler as it does with the ordinary, when high rates of evaporation are attempted. The matter can be well shown by a diagram (Fig. 14). In this figure, boiler efficiencies are plotted against rates of evaporation per square foot of boiler heating surface only. The line marked B D is the curve given by Bryan Donkin (on page 223 of his book on "Heat Efficiency of Steam Boilers") as the mean of the results of 377 experiments made upon various types of boiler by standard authorities. The line L F expresses the average of the results given by Mr. Lawford Fry in his great paper on locomotive boilers. The line marked Y Y is plotted from Mr. Yarrow's tests with a Yarrow boiler, as reported in 1898 to the Institution of Naval Architects. Lines marked M L, *a*, and *b*, give the efficiencies and rates of evaporation (per square foot of boiler surface), as reported by Mr. Longridge.

It is seen at a glance that, as Mr. Longridge puts it in his report, "no other boiler has given so high an evaporative efficiency combined with so high a rate of evaporation per

* Paper read before the Institution of Engineers and Shipbuilders of Scotland.

square foot of heating surface." The dotted line marked B B gives the results of the best trials on record.

When it is remembered that on the trials of the author's boiler from 10 to 15 per cent. of all the heat in the fuel was wasted by small coal blown away, owing to the hard firing with small and dusty coal, which was necessitated by the unduly small grate area (18·1 square feet for 7,000lbs. of steam per hour), and that those losses can be largely, if not altogether, eliminated by a larger grate area and easier firing, or by a more successful application of the reverberatory chamber principle behind the fire bridge, the author thinks his readers will not demur to the claim that it may confidently be expected that a high-speed counter-flow boiler to give a net efficiency of 80 per cent. when evaporating at the rate of 20lbs. of steam per square foot of heating surface per hour will shortly be constructed.

3. Freedom from choking up of the narrow flues and of corrosion at the outlet ends.

Since being erected in its present form, the boiler has been run for 60 days at draughts from 15in. to 20in. of water gauge for eight hours per day, and has stood with a banked

TABLE V.—*Effect of Gas Speed on Rate of Evaporation and Efficiency.*

Trial.		Bryan Donkin.			Mr. Longridge on Author's Experimental Boiler, October, 1909.					
		Page 32. No. 24.	Page 37. No. 6.	Page 45. No. 46.	14.	19.	12.	20.	21	1
Average Gas Speed		10	18	22	73	86	99	101	105	2
Evaporation from and at 212° per sq. ft. of heating surface per hour	Boiler only	4·51	7·2	8·3	11·87	15·44	19·25	22·77	23·06	3
	Boiler and Economiser	1·58	1·46	3·5	6·56	8·53	10·65	12·58	12·75	4
Thermal Efficiency	Gross	79·6	61·2	64	79·1	77·6	77·4	73·8	75·0	5
	Net				68·9	69·1	66·0	64·4	66·1	6

fire for the remaining 16 hours of those days. The extension of the run for this length of time without the necessity (as, indeed, there was not the possibility) of cleaning the gas side of the heating surface from soot in the narrow parts of the flues, appears to have conclusively established the fact that the scouring action of the high-speed gas flow is quite sufficient to prevent choking by the accumulation of adhering dust or soot to such an extent as materially to affect the rate of heat transmission. There is a permanent thin coating of dust on all the tubes; but it seems rather to operate as an excellent preventive of external corrosion than to be seriously effective in obstructing heat flow. The fact remains that, notwithstanding this coating of soot (of about $\frac{1}{32}$in. thickness), the heat transferring power is so much improved by the high gas velocity that the high rates of evaporation cited above are obtained, and the waste gas temperatures finally reduced to about 230° Fah., with feed entering at 75° Fah. This seems to the author a remarkable physical result. It is certainly of fundamental importance to the successful application of the high-speed principle to steam boilers fired with coal. Although there is no difficulty in arranging for narrow flues in the form of spaces between plane sheets of closely pitched tubes of small diameter, in such a manner that frequent cleaning of the surfaces by brushing can be carried out without trouble, yet the results of the 60 days' running of the experimental plant appear to show that such cleaning will be quite unnecessary, and that, on the contrary, the surfaces will maintain a permanent condition, under the action of the high blast, such that protection to the surfaces against corrosion will be afforded without obstruction to heat flow.

4. Complete avoidance of internal incrustation and corrosion by the use of high-speed directed flow of the feed water in narrow-bore tubes.

In the economiser of the experimental plant the $\frac{7}{8}$in. diam. tubes used were of $\frac{3}{4}$in. bore and 14ft. 6in. long; but each tube had a bar of $\frac{1}{2}$in. square stuff inserted throughout its length, so that the feed water had to thread its way through four narrow segmental spaces of $\frac{1}{8}$in. across at the widest part (Fig. 12). After use for 60 days and nights, with untreated canal water, the square bars were drawn out, and to quote Mr. Longridge's words, "were quite free from deposit or internal corrosion." This seems to the author indisputable evidence that all that is necessary in order to avoid incrustation and corrosion is the maintenance, by the use of small-bore water tubes (as few in number as the required area of flue suction will allow) of a sufficiently high speed of the feed water during the period of its heating to the boiling-point, and whilst it is giving up its air or other dissolved gases and

TABLE VI.

Date of Trial—October.	13.	14.	19.	20.	21.
Average Th.U. transmitted per square foot per hour (H) :—					
Through plug flue ...	33,400	12,200	14,540	32,400	32,200
Through evaporator tubes..................	6,850	5,130	5,480	6,550	7,530
Through economiser tubes..................	4,720	2,890	3,480	5,070	5,200
Mean temperature difference (△) between gas and steam or water :—					
In plug flue	1,811	1,242	1,191	1,830	1,859
In evaporator	726	586	568	771	798
In economiser	370	278	288	398	410
Average transmission per square foot per hour per degree (H ÷ △) :—					
Through plug flue ...	18·40	9·82	12·20	17·70	17·30
Through evaporator tubes..................	9·45	8·75	9·65	8·55	9·50
Through economiser tubes..................	12·76	10·4	12·1	12·73	12·70
Mean velocities of gas, feet per second (u) :—					
In plug flue u	104	64	75	105	110
In evaporator	106	75	90	110	115
In economiser	86	60	74	89	91
Mean densities of gas, lbs. per cubic foot (ρ) :—					
In plug flue	0·0178	0·0209	0·0216	0·0176	0·0173
In evaporator	0·0279	0·0304	0·0306	0·0266	0·0267
In economiser	0·0432	0·0465	0·0458	0·0419	0·0421
Values of $u\,\rho = \left(\frac{w}{a}\right)$:—					
In plug flue	1·67	1·27	1·55	1·67	1·72
In evaporator	2·89	2·20	2·68	2·88	2·98
In economiser	3·46	2·65	3·20	3·45	3·57
Values of $\frac{H}{\triangle \rho u}$:—					
For plug flue	11·00	7·74	7·90	10·60	10·10
For evaporator	3·28	3·98	3·64	2·96	3·19
For economiser	3·69	3·93	3·77	3·70	3·55

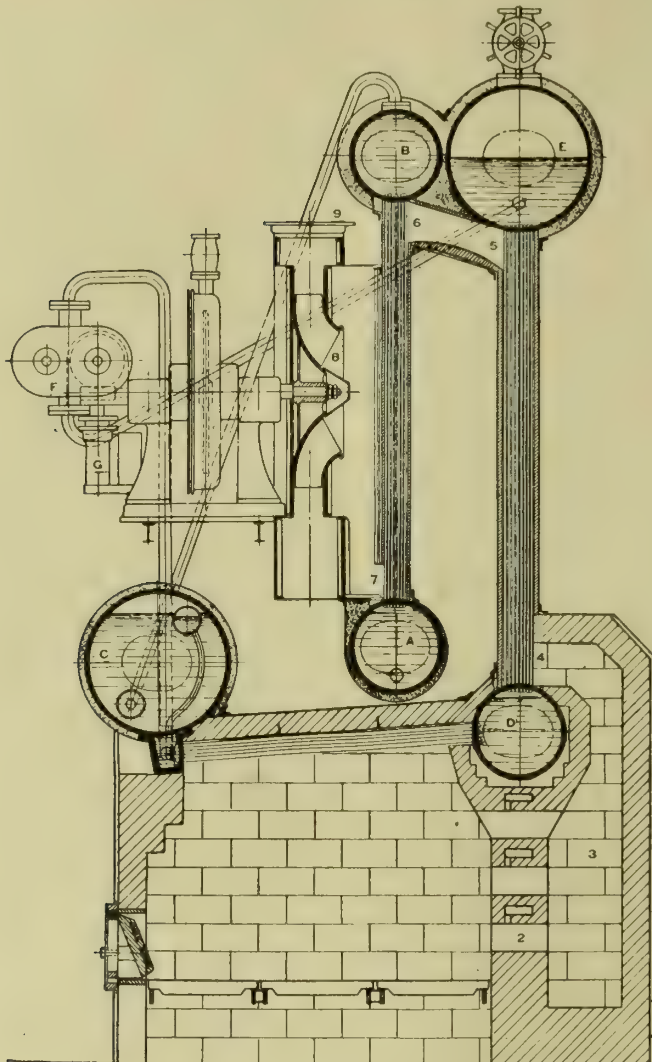
its impurities, *e.g.*, carbonates and sulphates. In this way pitting and corrosion are prevented, because they can only go on when air bubbles are allowed to adhere to the tubes, as when the water has only a slow movement or is altogether stagnant. If the water is rushed through narrow spaces at a high speed whilst throwing off its impurities, and is then led into a roomy space where these may settle without danger or trouble, before being passed through the evaporating tubes, the incrustation difficulty which has been so much held up against the adoption of small-bore tubes is really obviated by their use. With tubes of large bore, such as 1in. or more, the gas channels have to be of considerable width; that is, the tubes have to be widely spaced, and their lengths, for the large values of the surface-section ratio employed, become unmanageable. The water movement also becomes sluggish, and the deposit of adhering bubbles of gas and of solid incrustations is unavoidable. Thus, small-bore tubes are really a necessary accompaniment of high gas speed. If the high gas speed causes great rates of heat transmission, then rapid circulation is necessary to keep the tubes cool, and

a high water speed can only be obtained by tubes of small bore if the gas channels are narrow.

5. The degree of verification of Osborne Reynolds' law of heat transmission has been to some extent studied by Mr. Longridge on pp. 7 and 8 of the report. The method is as follows:—

For roughly correct estimates, Osborne Reynolds' law may (as already stated) be written—

$$H = c\rho u\Delta = c\frac{w}{a}\Delta \quad \dots \quad \dots \quad \dots \quad (1)$$



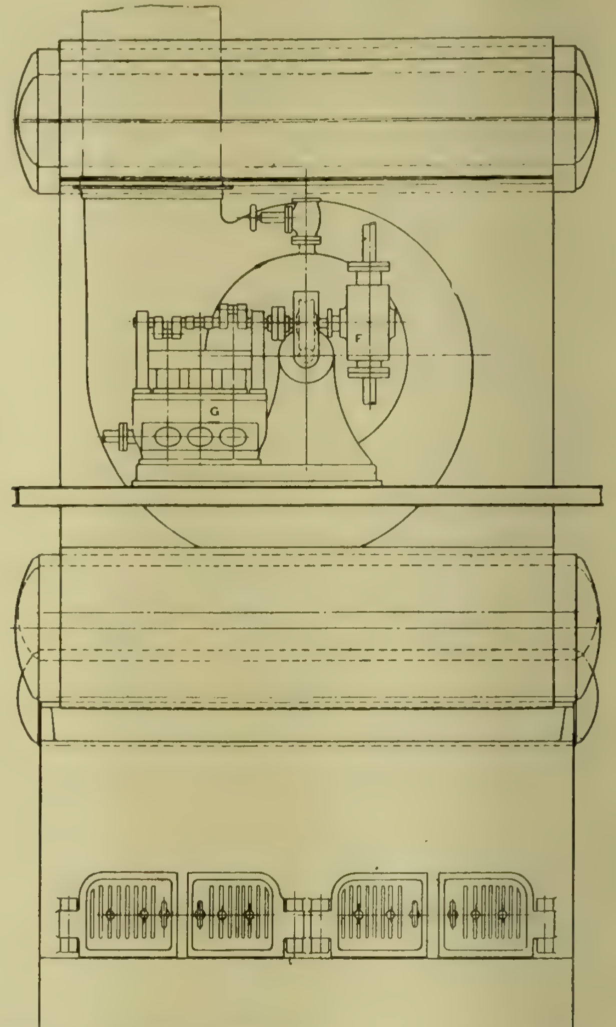


FIG. 15.—HIGH-SPEED BOILER. SECTIONAL ELEVATION AND FRONT VIEW.

where ρ is the density of the hot gases (lbs. per cubic foot).
u is the velocity of the hot gases (feet per second).
w is the weight of gas passing per second (lbs.).
a is the area of cross-section of the flues through which the gases pass (square feet).
Δ is the average difference between the gas and water temperatures (degrees Fah.).
c is a supposed constant quantity.

Since $w = \rho a u$; therefore $\frac{w}{a} = \rho u$; and either of these quantities may be described as the mass-flow per second per unit of area of flue section. To determine whether c is a constant, the value of

$$c = \frac{H}{\rho u \Delta}$$

has to be found for several different experiments in which, whilst Δ varies but little, ρu varies as much as possible. These things being premised, a direct quotation from Mr. Longridge's report may now be made as follows:—

"The heating surface of the flue beyond the combustion chamber was 130 sq. ft. The heat lost by the gases per hour in passing over this surface was $w\sigma\ (T_1 - T_2) \times W$, where $w\sigma$ is the heat capacity of the gases per pound dried coal given in line 23*a*, total. T_1 and T_2 the temperature of the gases entering and leaving the flue, given in lines 22*c* and 22*b*. W the weight of dried fuel fired per hour, given in line 14*a*. The numerical values of this expression divided by the heating surface give the average transmission through plates per square foot per hour. And this average transmission divided by

$$\frac{T_1 + T_2}{2} - t \ (t = 350),$$

gives the heat transmitted per hour per square foot of heating surface per degree of difference between the mean temperature of the gas on one side of the plate and the temperature of the water or steam on the other. Similar calculations can be made for the evaporator and economiser, whose heating surfaces were 192ft. and 293ft. respectively. The velocities and densities of the gases entering and leaving the plug flue, the evaporator, and the economiser are given in line 56*f* to 56*o*, and from them the mean velocities u, the mean densities ρ, and the mean value of $u\,\rho$ can be calculated. The result of the calculations will give the figures needed to answer the questions 4*a* and 4*b*. (*See* Table VI.) If the transmission per square foot per hour per degree temperature difference were strictly proportional to the product of the density and speed of the gas, the values of $H \div \Delta\rho u$ would be constant in each of the above lines, though these constant values might be different for the plug flue, for the evaporator, and for the economiser. The table shows that in the case of the economiser they are approximately constant, and, therefore, approximately in accordance with the law $H \div \Delta\rho u =$ constant. In the case of the evaporator the variation is greater, and for this there are two reasons—first, greater uncertainty as to temperatures and radiation losses; second, the fact that owing to some of the tubes being bent the gas current was not evenly distributed over the cross-section of the flue. In the case of the plug flue, the variation is consider-

able; but here it must be remembered that the plug was white hot at one end and more than red hot at the other, and, therefore, that the radiation from it was very great, consequently the heat absorbed by the flue plate was much greater than if the plate had received heat from contact with the hot gases only. This explains why the transmission was greater in the plug flue than it was in the evaporator and economiser, and why it was greater on the 13th, 20th, and 21st than on the 14th and 19th, when the temperature of the plug was lower."

In that part of the boiler where the radiation was negligible, *e.g.*, the economiser, it was therefore found that the law

$$Q = c_1 \rho_1 u_1 \triangle$$

was approximately true; the constant having the value $c_1 = 3{\cdot}73$ as an average of five trials. Taken in conjunction with the numerous other experimentally determined values the author brought forward in his paper before the Junior Institution of Engineers, p. 242, he submitted that Osborne Reynolds' law had been shown to hold over a great variety of conditions; and if used in the more extended form given above, he was prepared to show, had time and space permitted, that the formula he had brought forward contained a roughly correct approximation to the truth.

PART VI.—RATIONAL DESIGN OF STEAM BOILERS.

The author now proceeds to show how, by the application of Stefan-Boltzmann's law of radiation, and Osborne Reynolds' law of heat transmission, the designing of a steam boiler may be rationally carried out, with the assured expectation that the results actually obtained on trial will be in close accordance with those predetermined by calculation. The general type of boiler selected for study is the high-speed counter-flow boiler, shown by Fig. 15. The furnace (1) is not arched over with firebrick, but tube surface is provided to take the fire radiation for evaporative purposes. A reverberatory chamber (2, 3) is provided between the fire and the evaporator for the purpose, already alluded to, of completing combustion, so that not only all unburnt gases, but also all small coal blown out of the fire may be entirely burnt with an additional supply of air. The products of complete combustion then pass through the evaporator (4, 5), which consists of sheets of closely-pitched tubes ⅝in. diam. and ⅜in. bore, expanded into headers at each end, and enclosed in a sheet-steel casing lined with thin firebricks, with hollow spaces for air behind. The gas flue is formed by the spaces between the tubes and within the casing.

From the evaporator the gases pass through a similarly constructed nest of tubes, called the economiser (6, 7), to the fan suction (8). The cold feed enters at A, passes up through the (½in. diam., ¼in. bore) tubes of the economiser, in counter-current to the gases, to the drum B. The proportions are such that the feed is brought almost to the boiling point by passage through the economiser, and most of the evaporation is done in (4, 5). If the feed is impure, a mud drum C is provided, and the boiling feed is led thereto from B. After settling, it is led by a number of bent pipes in C to the U-shaped chamber below C, and is forced to pass along the radiation tubes to D. Thence it goes viâ the "convection evaporator" tubes to the steam drum E. The fan is driven by a steam turbine, and draughts up to 50in. or 60in. of water gauge can be induced in the fan suction (8) by one wheel only, running at from 2,000 to 3,000 revs. per minute. The main feed pump G and rotary pump F are driven through worm gearing by the same turbine. The rotary pump F can draw water from E and discharge it viâ the radiation evaporator and drum D back into E, so as to prevent these tubes from being burnt when the main feed is turned off. When under full steam, experience has shown that the circulation due to the main feed pump alone is sufficient to keep the tubes in (4, 5) quite cool; and F can be stopped. The power of the boiler is instantly varied by the steam supply to the fan turbine; and owing to the small volume of water to be initially heated, the full steam pressure can be got up from cold within 15 minutes, provided stand-by steam for the turbine is available.

The general heat equations fundamental to the design of such a boiler may be written down as follows:—

Heat generated in the fire = heat radiated + heat given to gases -

$$Q - 50F = \frac{1600}{F}\left(\frac{\tau_0}{1000}\right)^4 + k_p(A+1)(\tau_0 - 521) \quad . \quad . \quad (1)$$

The solution of this equation for any given rate of firing gives the fire temperature (T_0).

Heat radiated from fire per pound of coal = weight of water evaporated in furnace per pound of coal × latent heat (from and at steam temperature).

$$\frac{1600}{F}\left(\frac{\tau_0}{1000}\right)^4 = \frac{R}{F} = e_1 L \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Thus the evaporation due to radiation is known. If there be no ultimate furnace loss, *i.e.*, if all the furnace loss (50 F units per pound of coal) be recovered in the reverberatory chamber, the gases will rise in temperature from T_0 to T_1, according to the equation,

$$50F = \sigma(T_1 - T_0) \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where $\sigma = k_p(A+1)$.

Hence T_1, the temperature at entry to the evaporator, is known. (This neglects convective evaporation in the furnace, which is relatively small.) In ordinary dry boilers we may take $T_1 = T_0$.

If one assumes a waste gas temperature, T_3 (say, 220° Fah. for a counterflow high-speed boiler), then the total evaporation per pound of coal, e, is known from

$$Q - \sigma(T_3 - 60) = e[L + t - 60]. \quad . \quad . \quad . \quad . \quad (4)$$

Hence $e_2 = e - e_1$, the weight to be evaporated in the convective evaporator, is now known.

T_2, the gas temperature at entry to the economiser, can now be found, for the heat lost therein by the gases per pound of coal = the heat required to raise the whole of the feed evaporated per pound of coal (e), from 60° to the boiling point (t).

$$\sigma(T_2 - T_3) = e(t - 60) \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Finally, and, as a check, the temperature drop from T_1 to T_2 taking place in the evaporator, multiplied by the thermal capacity of the gases from 1lb. of coal, should be the equivalent of the convective evaporation $e_2 = (e - e_1)$ pounds of steam from and at the steam temperature (t) per pound of coal; or

$$\sigma(T_1 - T_2) = e_2 L \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The value of the product of the density and speed of the gases through the flues must now be determined; or (what is the same thing) their rate of mass-flow pounds per second per square foot of cross-section thereof $\left(\rho_1 u_1 = \frac{w_1}{a_1} = M_1\right)$. The usual value in ordinary boilers of this quantity is from 0·25 to 1; but in locomotive and destroyer boilers it sometimes reaches 3 or 4. In high-speed boilers it may have values up to 12, or even more, according to the relative values of floor space and of steam generated. The greater the value of the space saved by the use of the high gas speed, or of the diminished weight of boiler secured by increasing the rate of heat transmission and so reducing the area of the heating surface, the larger the amount of steam which can profitably be wasted on the fan plant and the higher the value of $M_1 = \frac{w_1}{a_1}$. The mass-flow (M_1) having been fixed from such considerations, and (w_1) the weight of gas discharged per square foot of fire being fixed by the rate of combustion decided on,

$$w_1 = \frac{(A+1)F}{3{,}600} = \frac{300 + 10F}{3{,}600} = \frac{1}{12} + \frac{F}{360}$$

then

$$a_1 = \frac{w_1}{M_1}, \text{ and the flue section is known} \quad . \quad . \quad (7)$$

If in this expression w_1 represents the weight of gases passing per second per square foot of grate area, then a_1 will

be the cross-section of the flue per square foot of grate area (sometimes called the "calorimeter"!).

The economiser heating surface per square foot of grate area can now be found:—

$$^{(*)}\quad \frac{s_{ev}}{a_{ev}} = \frac{l_{ev}}{m_{ev}} = \frac{B_{ev}\,k_1\,(1+R\beta)}{R\beta}\log_\epsilon\frac{T_1-t}{T_2-t} \quad . \quad . \quad (8)$$

Similarly, the evaporator heating surface per square foot of grate area can be found, for

$$^{(*)}\quad \frac{s_{ec}}{a_{ec}} = \frac{l_{ec}}{m_{ec}} = \frac{Kk_1}{K-1}\,\frac{c_1c_2R\beta}{c_1+c_2R\beta}\log_\epsilon\frac{T_2-t}{T_3-60} \quad . \quad (9)$$

In these formulæ put

$$K = \frac{w_2}{k_1w_1} = \frac{eF}{k_1(300+10F)} = \frac{T_2-T_3}{T_2-t_3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

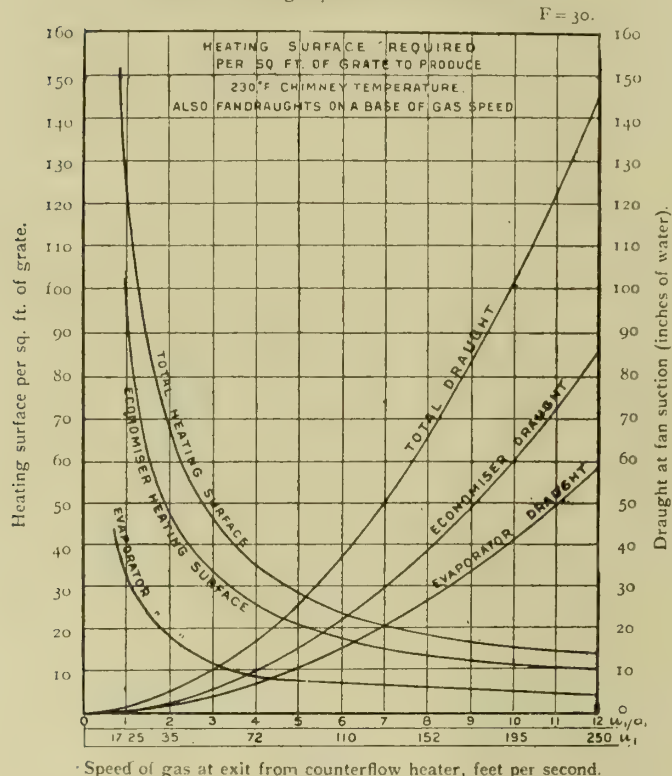
$$R = \frac{\rho_2u_2}{\rho_1u_1} = \frac{w_2/a_2}{w_1/a_1} = \frac{M_2}{M_1} \quad . \quad (11) \left\{\begin{array}{l}\text{in which } M_2 \text{ may be}\\ \text{taken equal to 60.}\end{array}\right.$$

$$\beta = \frac{d_2}{d_1} = \frac{\text{diameter of tube on water side}}{\text{diameter of tube on gas side}} \quad . \quad . \quad . \quad . \quad (12)$$

$B_2 = 600$ according to Stanton's experiments.

$B_{ec} = 1{,}000$ for the economiser } from the author's experi-
$B_{ev} = 600$ for the evaporator } ments.

Boiler with high-speed counterflow heater.



· Speed of gas at exit from counterflow heater, feet per second.

FIG. 16.

If the nests of tubes be of outside diameter d_1 inches, pitch p inches, and length l feet, and there be n tubes per square foot of grate, then (for hexagonal pitching)

$$(0{\cdot}866p^2 - 0{\cdot}7854d_1^2)n = 144a_1 \quad . \quad . \quad . \quad . \quad (13)$$

in which a_1 is known from equation (7), and, therefore, n is determined. Again,

$$\frac{n\pi d_1}{12}\,l_{ec}\,(\text{or } l_{ev}) = s_{ec}\,(\text{or } s_{ev}) \quad . \quad . \quad . \quad . \quad (14)$$

and since s_{ec} (or s_{ev}) are known from equations (8) and (9), l, the length of the tubes, is known.

In the present case take $F = 30$, as being near the value of F (Fig. 3), which gives best furnace efficiency. Then $A + 1 = 20$; $k_1 = 0{\cdot}24$; pressure by gauge, 150lbs. per sq. in.; feed temperature, $t_3 = 60°$ Fah.; waste gas temperature, $T_3 = 220°$ Fah.; it is found that $T_o = 2{,}210°$ Fah.; $T_1 = 2{,}522$; $\frac{R}{F} = 2{,}700$ thermal units per lb. of coal; $e_1 = \frac{2{,}700}{856} = 3{\cdot}15$lbs. from and at 366° Fah.; $e = 11{\cdot}82$, the evaporation from 60° Fah. at 366° Fah. per lb. of coal. $e_2 = 11{\cdot}82 - 3{\cdot}15 = 8{\cdot}67$. $T_2 = 975°$ Fah.; $w_1 = \frac{F(A+1)}{3{,}600} = \frac{1}{6}$lb. per second.

(*) For the deduction of equations (8) and (9) see Appendices II. and III.

TABLE VII.—*Particulars of High-speed Boilers with Various Draughts to Evaporate 10,000lbs. of Useful Steam of 150lbs. Pressure from Feed at 60° Fah.*

Economiser portion.

1	Mass-flow lbs. per second per sq. ft. of flue (M_1).	1	3	6	9	12
2	Average gas speed, feet per second (u_1) ...	56	166	333	500	666
3	Flue area per sq. ft. of grate (a_1)	0·1666	0·0555	0·0278	0·0185	0·0139 sq. ft.
4	Mass flow ratio (R)	60	20	10	6·66	5
5	$\frac{(B_2+B_3\,R\beta)}{R\beta}$	1,020	1,060	1,120	1,180	1,240
6	Number of tubes per sq. ft. grate (n) (½in. tubes pitch ¾in.) ...	82·6	27·5	13·75	9·17	6·88
7	Heating surface of 1 running foot of n tubes	10·35	3·6	1·8	1·2	0·9
8	Surface section ratio S_{ec}/A_{ec} ...	548	570	602	634	666
9	Heating surface required per sq. ft. of grate (s_{ec})	91·4	32·65	16·73	11·8	9·28
10	Length of tubes, feet	8·83	9·07	9·3	9·8	10·3

$K = 2{\cdot}47$; $\rho_2u_2 = 60 \times 1 = 60$; ρ_1u_1 variable, as shown in Table VII.

$$e = \frac{d_2}{d_1} = \frac{0{\cdot}25}{0{\cdot}5} = 0{\cdot}5. \quad \frac{Kk_1}{(K-1)} = 0{\cdot}403$$

$$\log_e\frac{T_2-t}{T_3-60} = \log_e\frac{974-366}{220-60} = \log_e\frac{608}{160} = \log_e 3{\cdot}8 = 1{\cdot}3350.$$

TABLE VIII.—*Evaporator portion.*

20	Mass-flow lbs. per second per sq. ft. of flue (M_1)......	1	3	6	9	12
21	Average gas speed, feet per second (u_1)	27	81	168	270	406
22	Flue area per sq. ft. of grate (a_{ev}) ...	0·1666	0·0555	0·0278	0·0185	0·0139 sq. ft.
23	$6{\cdot}32(M_1+30)$ surface — section ratio...............	195·8	208·5	227·5	246·5	265
24	Heating surface per sq. ft. of grate (s_{ev})	32·62	11·57	6·32	4·56	3·68
	Steam per sq. ft. of heating surface of evaporator per hour ...	10·87	30·65	56·1	77·8	96·4
25	Number of tubes per sq. ft. of grate (n)	37·34	11·93	5·97	3·98	2·99
26	Surface (½in. tubes, pitched 1in). of 1ft. of n tubes	4·89	1·561	0·78	0·52	0·391
27	Length of tubes, feet	6·68	7·41	8·10	8·77	9·42
30	Total heating surface of evaporator and economiser per sq. ft. of grate...	124·02	44·22	23·05	16·36	12·96
	Steam per sq. ft. heating surface per hour, total..	2·855	8·02	15·4	21·65	27·35

Thus, the surface-section ratio for the economiser is—

$$\frac{s_{ec}}{a_{ec}} = 0{\cdot}403 \times 1{\cdot}335 \begin{Bmatrix} 1020 \\ 1060 \\ 1120 \\ 1180 \\ 1240 \end{Bmatrix} = \begin{Bmatrix} 548 \\ 570 \\ 602 \\ 634 \\ 666 \end{Bmatrix} \text{ for } M_1 = \begin{Bmatrix} 1 \\ 3 \\ 6 \\ 9 \\ 12 \end{Bmatrix}$$

Now, $a_1 = \frac{w_1}{M_1} = \frac{0{\cdot}1666}{M_1}$. Take the tubes to be ½in. outside diameter and ¾in. pitch; the area for gas per tube is $(0{\cdot}866p^2 - 0{\cdot}7854d^2) = 0{\cdot}291$ square inches and $n = \frac{a_1}{0{\cdot}291} = \frac{0{\cdot}166 \times 144}{M_1 \times 0{\cdot}291}$.

The resulting quantities are given in the annexed Table VII. (lines 1 to 10). Similarly for the evaporator, F = 30; A + 1 = 20 : $w_1 = \frac{1}{6}$, as before. k_1 must now he taken = 0·25 to allow for increase of specific heat of CO_2 with temperature;

$$\log_e \frac{T_1 - t}{T_2 - t} \left(= \frac{2522 - 366}{975 - 366} = \frac{2156}{609} = 3{\cdot}54 \right) = \log_e 3{\cdot}54 = 1{\cdot}2641.$$

If the tubes are, as before, ½in. in diameter and ¼in. bore, then:

$$\frac{Re}{1 + R_e} = \frac{30}{M_1 + 30} : c_1 = 6.$$

So that:

$$\frac{6}{3600} \frac{30}{(M_1 + 30)} \frac{4l}{d_1} = 1{\cdot}2641,$$

or

$$\frac{s_{ev}}{a_{ev}} = \frac{4l}{d_1} = 5\,(M_1 + 30) \times 1{\cdot}2641 = 6{\cdot}32\,(M_1 + 30).$$

The results are tabulated in lines 20 to 27 of Table VIII. The heating surfaces of economiser, evaporator, and the whole boiler have been plotted on a base of gas-speed or mass-flow on Fig. 16.

(*To be continued.*)

THE MELTING POINTS OF FIREBRICKS.

IN a technologic paper to be issued shortly by the U.S. Bureau of Standards the results of some experiments to ascertain the melting points of firebricks are given by C. W. Kanolt as follows:—

We are accustomed to thinking of a melting point as a temperature at which a substance changes from a rigid to a fluid condition, but a melting point can be precisely and rationally defined only as the temperature at which a crystalline or anisotropic phase and an amorphous or isotropic phase of the same composition can exist in contact in equilibrium. While this definition is satisfactory for pure substances, so complex a mixture as an ordinary firebrick usually has no single definite melting point according to this definition, since several anisotropic phases may be present, all differing in composition from the isotropic phase produced by fusion. We can then only select the temperature at which the transition from a rigid to a fluid state seems most distinct, and can call this the melting point only by apology. In the case of firebricks, the transition temperatures so found are, fortunately sufficiently distinct. I have taken as the melting point the lowest temperature at which a small piece of the brick could be distinctly seen to flow.

The experiments were conducted in an Arsem graphite resistance vacuum furnace. The samples were usually enclosed in a refractory tube made of a mixture of kaolin and alumina in the proportions to form sillimanite, to protect them from the small amount of reducing gas in the furnace, although the action of this gas was slight. The samples were observed through a glass window in the top of the furnace.

The temperatures were determined by means of a Morse optical pyrometer of the Holborn-Kurlbaum type, which was sighted vertically downward through the glass window. The carbon-filament pyrometer lamp was calibrated by two methods. In the first calibration it was sighted into a platinum resistance furnace in which black-body conditions were obtained, and the temperature of which was measured by platinum platinum-rhodium thermocouples. These thermocouples had been calibrated against the freezing points of pure metals. In the second calibration the lamp was calibrated against the freezing points of metals directly, without the intermediation of thermocouples. The metals used were copper, silver, and the copper-silver eutectic, which freeze at 1,083°, 961°, and 779°, respectively. The metals were melted in the vacuum furnace in graphite crucibles, the pyrometer being sighted into a thin-walled graphite tube inserted in the metal. The pyrometer readings corresponding to the freezing points were determined by means of cooling curves. With silver and copper, heating curves were also obtained.

As the melting points to be measured were above the working limit of the pyrometer lamp, an absorption glass was interposed between the pyrometer and the furnace. The true temperatures were then found from the apparent temperatures measured through the glass, by means of the equation

$$\frac{1}{T_2} - \frac{1}{T_1} = A,$$

where T_1 is the absolute temperature of the furnace, T_2 is the apparent temperature observed through the glass, and A is a constant. The value of A was determined by calibrations at various temperatures. A small correction was also applied for the absorption and reflection of the glass window of the furnace.

The samples, which were from 1 cm. to 2 cm. diam., were heated at the rate of about 10° per minute when near the melting point. It was found that in the case of certain bricks made of heterogeneous material of relatively low melting point the melting points were slightly higher after six hours' heating to 1,550°, apparently as the result of the gradual running together of dissimilar particles to form a mixture having a higher melting point than the most fusible of the original materials. The results are summarised in the following table:—

Material.	Number of Samples.	Melting Point. Deg Centigrade.
Fireclay brick	41	1,555° to 1,725° mean 1,649°
Bauxite brick	8	1,565° to 1,785°
Silica brick	3	1,700° to 1,705°
Chromite brick	1	2,050°
Magnesia brick	1	2,165°
Kaolin	3	1,735° to 1,740°
Bauxite	1	1,820°
Bauxite clay	1	1,795°
Chromite...	1	2,180°
Pure Alumina	—	2,010°
Pure Silica	—	1,750°

The value 1,750° C. given for silica is not the true melting point, but represents approximately the temperature at which the silica flows distinctly. It was found that silicon carbide does not melt below 2,700° C.; it becomes unstable at much lower temperatures.

SULZER'S VALVE GEAR FOR INTERNAL-COMBUSTION ENGINES.

WE illustrate herewith an arrangement of valve gear for continuous-combustion internal-combustion engines, the invention of Messrs. Sulzer Bros., Winterthur. The gear has been designed with the object of improving and simplifying the arrangement of the safety valves and inlet valves used for the admission of compressed air for starting, reversing, or the like. As at present made internal-combustion engines of this type have separate and independent safety valves and inlet valves for the compressed air. The arrangement under notice is such that a single valve and its controlling mechanism is alternately used as a safety valve and as an inlet valve for admitting compressed air into the engine cylinder for starting or reversing. By a single movement of the controlling mechanism, the valve can be set for starting whereby its action as a safety valve is simultaneously neutralised, or its use as a starting valve can be discontinued, whereupon the valve immediately serves once more as a safety valve. Two constructions are shown in the accompanying illustrations. Figs. 1 and 2 show diagrammatically one arrangement adapted for a single-cylinder engine or for an engine with several cylinders where each cylinder has a separate controlling apparatus, and Fig. 3 is a similar view of an arrangement in which a single mechanism controls two cylinders.

Fig. 1 shows the position in which the valve member acts as a safety valve, and Fig. 2 shows the position of the device during the starting of the engine by means of compressed air. The cylinder of the internal-combustion engine F has a piston K and the cam shaft is shown at R. The valve member A, which may be of the slide, piston poppet, or other type, controls admission to the cylinder F, and is opened or closed by means of a lever B pivoted at C. The opening is effected by raising a rod D, provided with a stop E, on which a spring bears normally tending to close the valve A. The tension of the spring is calculated in such a manner that on the pressure in the engine cylinder reaching a certain value, the valve A is opened. The upward movement of the rod D is effected by shifting a rod G having a stop H which engages the stop E. The upward movement of the rod G can be effected by turning a hand wheel J and introducing a pressure medium under the piston L. The travel of the rod G or of the piston L is limited by a stop. For the admission of compressed air for starting or reversing, a slide valve N is provided, which is adapted to be reciprocated in its casing O by an eccentric P through the rods and rocking lever shown. The valve casing O is connected both to the pumps and reservoirs supplying the compressed air by means of a pipe S, and also to the atmosphere by means of the pipe T. A pipe U connects the valve chamber O to the casing of the valve A. The pivot point V of the rocking lever is on the rod G which controls the position of the valve A. It will therefore be seen that the pivot point V of the balance lever will be shifted in accordance with the position of the rod G, which results in the position of the valve A and of the "zone of movement" of the slide valve being interdependent. When the valve A is opened by means of the rod G, the slide valve N will be in its upper zone of movement. When it is closed, the slide valve N will be in its lower zone.

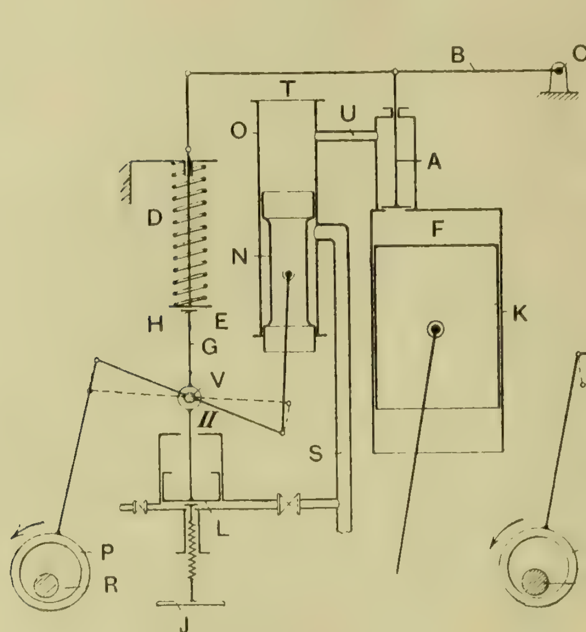


Fig. 1.

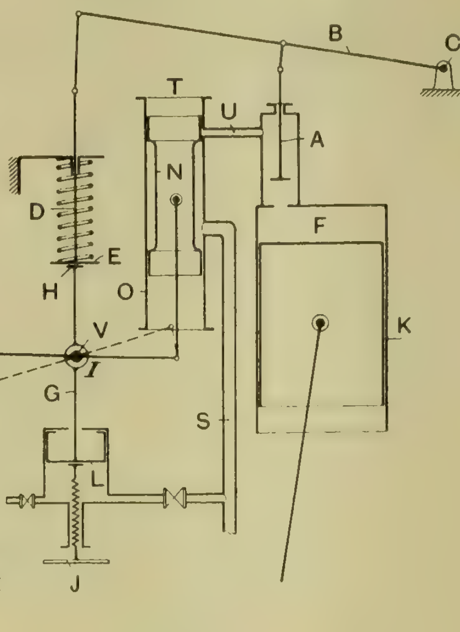


Fig. 2.

SULZER'S VALVE GEAR FOR INTERNAL-COMBUSTION ENGINES.

The operation of the arrangement is as follows: If the engine is to be started by means of compressed air, the rod G, and therefore also the rod D, are brought into the upper position I, as shown in Fig. 2. In that way, in the upper position of the rod D, the starting valve A will be permanently opened. At the same time this movement brings the slide valve N into its upper zone of movement, and therefore the compressed air charge is introduced near the upper dead centre. When it is desired to change to working with fuel, the rod G, and therefore also the rod D, must be brought into their lower position II. (Fig. 1). In that way the valve A is closed, and the slide valve N brought into its lower zone of movement. In this lower position the slide valve permanently, or only near the upper dead centre of the piston K, establishes communication between the valve casing and the pipe T, that is to say, the atmosphere.

In the arrangement shown in Fig. 3, in which two cylinders are controlled by means of the same mechanism, the pipe S supplies compressed air for starting or reversing to the slide valve chest O, which communicates with the valves A by means of the pipes U. Connection with the atmosphere is effected through the open end of the slide valve chest O. A double slide valve N is employed to control the supply of compressed air. When the slide valve N is in the zone of movement on the left-hand side, which is the case in the position I, at the upper dead centre of the pistons K and Q of the cylinders F and M it establishes communication between the compressed air pipe S and the poppet valves A, for the purpose of starting the engine. If, however, the slide valve N is in the zone of movement on the right-hand side, it establishes communication permanently or only when the piston K is in the upper dead centre between the casings of the valves A and the atmosphere. The rods B, acting direct on the valve A, must be arranged in such a manner that the valves can open and close again independently of the rods D and G and of each other when they have to act as safety valves. In reversing engines the driving gear of the slide valve, as shown in Fig. 3, is provided with a device for altering the slide valve movement relatively to the time of the cycle of operations.

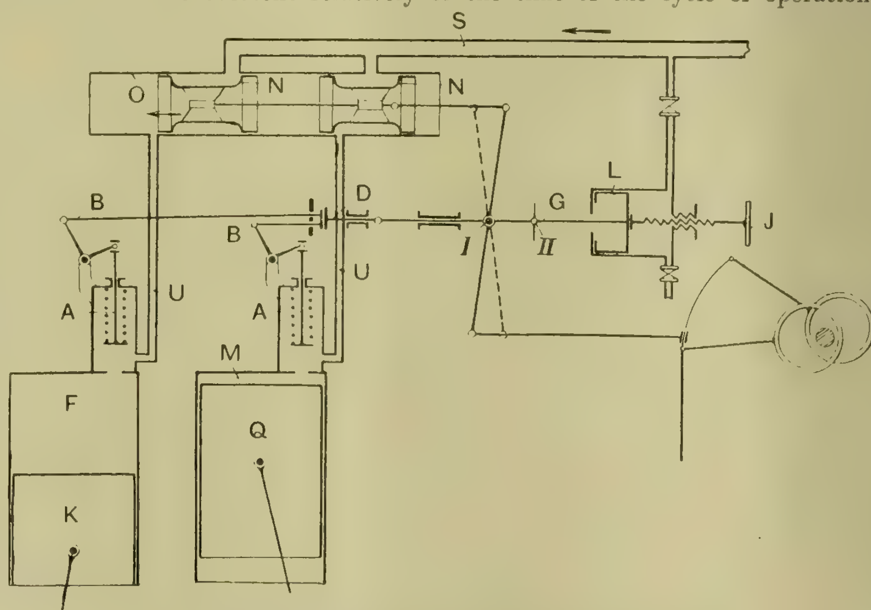


FIG. 3.—SULZER'S VALVE GEAR FOR INTERNAL-COMBUSTION ENGINES.

Personal.—Mr. Edmund Sharer, shipyard director at the Dalmuir naval construction works of W. Beardmore & Co., has severed his connection with that company, and will be succeeded by Mr. Archibald Campbell, naval architect, who at present represents Vickers, Ltd., John Brown & Co., and Armstrong, Whitworth, & Co., at the Ferrol dockyards in Spain. Mr. Campbell has been acting as principal shipbuilding director for the three companies named in connection with the reorganisation of the Spanish Navy.

COKING PRACTICE IN THE SOUTH WALES DISTRICT.*

BY R. H. GREAVES.

MUCH more importance is at present attached, to the selection of coke used in foundry work than formerly, and this care is not misplaced, as it leads to economy in melting and a higher quality of metal. In attaining the former result the physical character of the coke and the amount of ash are of importance: a high ash means a correspondingly low percentage of combustible matter, and also increases the amount of flux to be used. Sulphur present in the coke passes, to a considerable extent, into the metal, and exerts its own influence. In many cases in which castings come out hard the metal is blamed, whereas the fault lies entirely with the coke used: when coke is high in sulphur, the best metal will be ruined. In view of the importance of coke as a factor in foundry work, a short account of the production and character of South Wales coke may be of interest.

Welsh Coals.—The South Wales coalfield covers an area of nearly 1,000 square miles, and extends over the greater part of Glamorgan and Monmouthshire and into the counties of Pembroke, Carmarthen, and Brecon. The character of its coals—in some cases unique—is illustrated by the following typical analyses: —

Type of Coal.	Moisture.	Ash.	Volatile Matter.	Fixed Carbon.
	Per Cent.	Per Cent	Per Cent.	Per Cent.
Monmouthshire bituminous	1·0	6·8	27·5	64·7
,, steam	1·0	3·5	21·3	74·2
Best Welsh steam—Rhondda Valley	1·0	3·5	14·0	81·5
Dry steam—Aberdare Valley... ...	0·7	2·5	11·5	85·3
Anthracite—Swansea district... ...	0·9	2·3	5·1	91·7

The distribution of these types of coal conforms to two general rules: (1) on passing towards the N.W. and W. the seams become more and more anthracitic; while (2) at any given point, the lower seams have the smaller volatile matter. The true coking coals, containing upwards of 20 per cent. volatile matter, are thus found round the S. and E. outcrops of the coalfield and in the upper seams of the central districts. The small of steam coal and anthracite, of course, does not coke, but is admirably suited for the manufacture of briquettes or patent fuel, an industry in which South Wales takes the foremost place. The following are examples of Welsh coking coals: —

Seam.	Moisture.	Ash.	Volatile Matter.	Fixed Carbon.	Sulphur.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Black Vein...	0·80	4·28	25·64	69·28	0·6
Brithdir	0·90	2·60	26·0	70·5	2·6
No. 3 Rhondda...	1·50	2·50	24·8	71·2	0·8

As so many of the Welsh coals are non-caking, it is usual to mix these with caking coals in certain proportions. This practice dates from 1850, when a patent was granted to Mr. J. P. Budd, of Swansea, for the manufacture of coke from a mixture of non-caking and caking coals. From time to time coke has been made from pitch, and from crushed anthracite and pitch in varying proportions, but this has been given up. It is not likely that with pitch at its present price of 54s. per ton much will find its way to the coke oven. Pitch coke was strong, hard, exceedingly low in ash, and although somewhat porous, melted a very hot iron.

Local Conditions.—The mixture of coals is made as a rule to contain about 20 per cent. of volatile matter. This is a much lower figure than is employed in other districts; it accounts for differences in the development and present practice of coking in South Wales as compared with other coalfields, and also has an influence on the nature of the coke.

(1) There is a larger yield per ton of coal and a proportionately lower ash and sulphur. It is evident that a coal containing 5 per cent. ash will give a coke containing $5 \times \frac{100}{70} = 7{\cdot}14$ per cent. ash if the coke yield is 70 per cent.; whereas with an 80 per cent. yield the ash would be only 6·25 per cent.

(2) In the North, coals with 30 to 35 per cent. volatile matter are converted into fairly dense coke by compressing the slack in the ovens. Compression is never practised in South Wales, and would be undesirable, as the coke produced is already sufficiently dense. Moreover, the contraction on coking is small, and coke so compressed could not be easily pushed out of the ovens.

(3) It is now well recognised that a low volatile coal requires more rapid heating in order to obtain a satisfactory coke than a more bituminous one. This fact was early recognised in practice; it explains the widespread use in South Wales of the old Welsh oven to the exclusion of the Durham beehive, and the great popularity of the early retort ovens of the Coppée type.

Coal Washing.—Coke is produced from small coal; no large coal is ever used in any of the modern ovens. A large amount of slack is employed, and this generally contains an admixture of shale, which brings the ash up to 20 or 30 per cent. Before coking this is removed in a washery. The procedure varies with the system of washing employed, but in general coals are mixed in the required proportions and screened to separate different sizes—nuts, beans, peas, &c., each of which is washed separately; only coal of perhaps $\frac{5}{16}$in. or less is sent to the ovens. The principle of many types of washery is shown in Fig. 1.* Coal on the grid is washed by water supplied through K and kept in a state of agitation by the motion of the piston B. For the smalls, there is a layer of felspar on the grating. This is intermediate in density between coal and shale, and serves to effect a more complete separation. The fine dust passes through the grid and is from time to time collected at G, the larger shale is run off at E, while the coal is washed over at D. The most important washeries at work in the district are the Coppée, Shepherd,

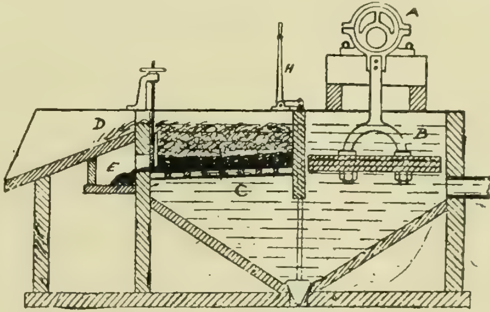


FIG. 1.—THE JIG WASHER.

and Baum; trough washers, such as the Elliott and Blackett, are also in use.

In washing, the ash is reduced from 20 or 30 per cent. to 6 per cent. or under; that is to about 2 per cent. more than the ash of the pure coal. For example, in a case in which the ash of the absolutely clean coal was about 3 per cent.: —

Before washing, whole coal contained			15·0 per cent. ash.	
After washing,	smalls	,,	5·5	,,
	beans	,,	4·0	,,
	nuts	,,	3·3	,,
	dust	,,	8·2	,,

Ash is difficult to remove from the very fine dust, and this is never used for better-class coke. Sulphur is very considerably reduced during washing, a large amount which occurs as "brasses" or iron pyrites being removed. Phosphorus, on the other hand, is not reduced, the coal substance apparently containing about the same percentage as the shale. The washed "smalls" are carried on an endless chain of buckets to bunkers to drain, the moisture being thus reduced to about 10 per cent. From the bunkers the coal is run in small trucks to the top of the ovens.

Development of Coking in South Wales.—The coke first produced in Wales was used entirely in the local ironworks. Up to 1840 Welsh ironmasters had never attempted any improvements on the old method of coking in piles covered with wetted coke dust from a previous operation. This method was soon abandoned at Merthyr, where the coal used passed "almost unchanged into a ponderous coke resembling anthracite." In many of the Monmouthshire works, where a more bituminous coal was available, the method was used at a very much later date. The piles were generally circular, about 18ft. diam. and 6ft. high, and were arranged round a central chimney,

* Paper read at the British Foundrymen's Association annual convention, Cardiff, August, 1912.

* Taken from Byrom & Christopher's "Modern Coking Practice," where a full description of most of the plant mentioned in this paper will be found.

through which they were fired. At Coalbrook Vale, Cyfarthfa, and other places, long piles, termed "pits," were made 12ft. wide, 3½ft. high, without any central chimney; these were ignited at the top, and damped down with wet coke dust until coked through, then quenched with water. Kilns were used for a short time, precisely similar to the Schaumberg kiln, though they were independently designed. The method was soon abandoned, and all traces of the kilns have disappeared. The coke had to be drenched with water, frequently taking up 20 per cent.; at the Dowlais works the yield was reported as "very bad indeed"; while the manager of the Ebbw Vale Company, commenting on the manner in which the coal burnt away, observed, "You might hunt badgers through the coke."

The oldest Welsh ovens were simple arched, rectangular chambers, in which air entered through the top of the door in front, and the burning volatile products escaped through a chimney at the back. At Dowlais Ironworks they were 13ft. long, 6ft. wide, and 4½ft. high to the top of the arch, and produced 50 cwts. of coke in 48 hours. In these ovens slack could be coked, whereas only a small proportion of this could be coked in heaps. The coalowners were quick to take advantage of this to reduce their huge accumulations of slack. No coal was washed before coking, and in many instances coking degenerated into a process for conglomerating small dirty coal, which would otherwise have been wasted. The product of these ovens often contained 20 per cent. of ash, while the sulphur was sometimes as high as 2·25 per cent.

No improvement took place until the Great Western Railway began to use large quantities of coke for their locomotives. This created a demand for a superior product, and more attentoin was paid to the purity of the coal used, to the design of the oven, and to economy of manufacture. For the removal of sulphur all sorts of suggestions were made, notably the treatment of the coke with steam and with various solutions, but the only satisfactory method is the use of washed coal. Economy was introduced in working by the use of the waste gases for steam raising. In 1848 blast-furnace gas was first utilised for this purpose at Ystalyfera, but coke-oven gas was not used until many years later. On account of the increased yield and rapidity of coking, the Coppée oven rapidly grew in favour; at present more than four-fifths of the Coppée ovens of the kingdom are situated in South Wales. They were introduced at Ebbw Vale in 1874, when two batches of 30 ovens were laid down. With the exception of those at Chapeltown, near Sheffield (built in 1873), these were the first in England. They are still working, together with others erected more recently. Until 1903 no by-product ovens were to be found in South Wales. There were very few tar-distilling works in the neighbourhood to form a local market for the by-products, and this fact, together with the low volatile matter of Welsh coals, made manufacturers somewhat sceptical at the time as to the return to be realised on their outlay. Since 1903, however, a number of by-product ovens of various types have been erected, and others are in course of construction.

Types of Ovens at Present In Use.—The official statistics of the number and kind of ovens in use in 1910 are as follows:—

	Glamorgan.	Monmouthshire.	Total for South Wales.	Total for United Kingdom.
Beehive	142	290	432	16,037
Simon Carves	—	—	—	1,140
Semet-Solvay	—	—	—	1,055
Coppée	1,004	606	1,610	1,991
Bauer	—	—	—	52
Koppers	—	100	100	507
Otto-Hilgenstock	82	—	82	1,025
Simplex	40	—	40	334
Hüssener	—	—	—	249
Others...	129	244	373	593
Totals	1,397	1,240	2,637	22,983

Most of the ovens given as beehives do not in the least resemble the round Durham beehive ovens, but are really the Welsh rectangular ovens. The fact that some of these have been returned as "Cox's ovens," and so appear under "others," adds to the uncertainty of the first and last lines.

Welsh Rectangular Ovens (Cox's Ovens).—The original rectangular coking chamber has been modified by the addition of flues, through which air is introduced for the combustion of the volatile matter, and by building gas flues at the side of and beneath the coking space. One arrangement (in use at Blaenavon) is shown in Fig. 2. The hot oven is charged with washed coal through two charging holes in the roof; volatile matter is expelled and burns in the air supplied by the flues A. The hot gases pass into the side flues B, circulate beneath the ovens, and are finally used for steam-raising under boilers. The coke is quenched partly inside and partly outside the ovens, and withdrawn by means of crabs, the floors being sloped to facilitate withdrawal. The ovens are built back to back in double rows, and give a yield of about 57 per cent. of coke. The important modification introduced by Cox is the provision of a second arch inside the oven, called the jack-arch. One of several types of oven in use at Ebbw Vale is shown in Fig. 3. These are also built back to back; every third oven is charged each day. The charge is introduced through the doorway and piled to a uniform height of 3ft. 6in.; the door is then let down and luted with clay. Volatile matter driven off by the heat of the oven burns in the space above the bed of fuel in air obtained through the flue A. The burning gas has to pass to the front of the oven, then over the jack-arch to the main flue and chimney. This is one of the earliest types; modifications include the provision of side flues on the left side of the ovens, and of flues underneath. In this case the air which supports combustion is admitted above the jack-arch, and not into the coking chamber. The charge is withdrawn after three days; yield about 58 per cent.

Coppee Ovens.—These are built in batteries of 30, and in pairs, one of each pair being charged when the contents of the other are half coked. The products of distillation from each pair pass to the same flue, thus rich hydro-carbons are supplied by the colder oven when the gas from the hotter begins to get poor in quality. The heat resulting from the combus-

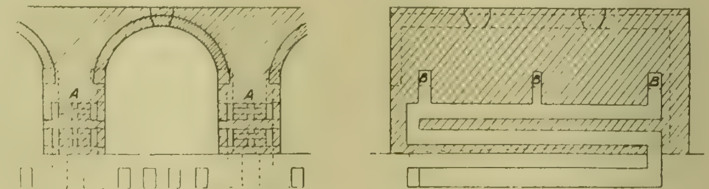


FIG. 2.—WELSH RECTANGULAR OVEN.
Length, 18ft.; breadth (back), 6ft., (front), 6ft. 6in.; height (front), 7ft. 3in.

tion of these gases is communicated chiefly to the pair of ovens from which the volatile products have been evolved, by passing them through vertical flues at the sides, and horizontal flues underneath the ovens. The waste heat is utilised under boilers, two of which are generally supplied by each battery of ovens. The yield of coke is about 68 per cent.

By-product Recovery Ovens.—These may be divided into ovens with vertical flues and those with horizontal flues, each group being further divided into regenerative and "waste heat" types. In the former, the sensible heat of the escaping gases is communicated to the air drawn into the flues; the gases may then be used in gas engines, or furnaces under boilers, or for illuminating purposes. In the latter type the gases escape at a high temperature, and must be used near the ovens for steam raising.

The only horizontal-flued oven in the South Wales coalfield is the Simplex at the Lewis Merthyr Colliery, Hafod, where 40 ovens of the waste-heat type have been in use since 1909. In this system the gas, after being free from tar and ammonia, is returned to the oven and burns at jets, each flue being supplied by a separate jet in order to obtain an even distribution of temperature. The hot gases which escape supply heat for four Lancashire boilers.

The vertical-flued ovens used in this district are the Otto-Hilgenstock, Koppers, and Coppée by-product ovens. A battery of 82 Otto-Hilgenstock waste-heat ovens was erected to the Great Western Colliery Company at Pontypridd in 1903, and started working in the following year. These were the first by-product ovens in the district. The purified gas in this case returns to the distributing main, and burns at jets in a long horizontal flue divided at the middle, out of which vertical flues rise at the side of the oven. The burning gases pass along an upper horizontal flue, then downwards on reaching the middle of the oven, and by a sole flue to the waste-gas

main, whence they pass under the boilers. At Pontypridd there are 10 burners in the length of the oven (33ft.); later forms have 15 burners, and differ in the arrangement of flues.

Otto-Hilgenstock ovens of the latest type, with regenerators, are in course of construction at Blaenavon. The spare gas (probably about 50 per cent. of the total, as compared with a maximum of 20 to 30 per cent. in the waste-heat type) will be applied to gas-engine or furnace work, or partly used for lighting purposes.

Two batteries of Koppers' regenerative ovens have been at work at the Powell Duffryn Colliery, Bargoed, since 1906 and 1907. The first set of 50 ovens has four regenerators common to all ovens, placed longitudinally along the full length of the bench; the second set has a separate regenerator under each oven, the reversing of gas and air being done simultaneously for the whole set. In this oven vertical flues communicate with the gas-distributing channel through orifices, each fitted with a nozzle which may be adjusted from the top of the oven. Dampers regulating the supply of air are similarly controlled, and the temperature of every part of the oven is thus easily regulated. The gas at Bargoed amounts to 10,000 cub. ft. per ton of coal, with an average calorific power of 460 B.Th.U. per cubic foot. It is purified in the ordinary by-product plant, and then deprived of sulphur, which is converted into sulphric acid for the manufacture of sulphate of ammonia. The surplus gas, which amounts to about 5,000 cub. ft. per ton, is used for gas engines, and, with incandescent mantles, as an illuminant. There are two gas engines of the Nürnberg type, of 1,200 b.h.p. and 2,400 b.h.p., also one of the Cockerill type, of 650 h.p., to drive a ventilating fan. The consumption of gas per brake horse-power is 21·3 cub. ft. (1 cub. ft. = 458 B.Th.U.).

The Coppée by-product oven is developed from the original Coppée oven. This type is employed at Lancaster's Steam Coal Collieries, Cwmtillery, and regenerative ovens are in process of construction at the Welsh Navigation Collieries, Coedely. One regenerator is connected with the sole flues of the odd, and the other with those of the even numbered ovens. The vertical side flues are divided into five sections, each of six flues. Burning gas passes up three of these and down the other three, the direction being reversed periodically. The air supply is driven through the regenerators by a fan, and its direction through the sole flues is reversed with the gas. The yield of coke made in by-product ovens varies in South Wales between 74 and 80 per cent. of the coal used.

Quenching.—The appearance of the coke depends largely on how quenching is carried out. By quenching out of contact with the air (as in the Durham beehive ovens), a bright, metallic surface is preserved. At Bargoed the coke is pushed out by a ram into a Darby quencher, which is a hood through which water issues at a number of jets and cools the coke in an atmosphere of steam. At other places numerous devices are employed, but it is always important to have a high-pressure water supply; the coke retains much less moisture when quenched with water at high pressure.

Recovery of By-products.—These are generally recovered in the ordinary way by drawing off the gas through a hydraulic main, then through air and water cooled condensers, which bring down most of the tar and ammonia liquor. The exhausters generally used for this purpose are the Bryan Donkin and the Beale. Thence the gas passes to a tar extractor (*e.g.*, the Pelouze), which separates the remainder of the tar, and to scrubbers, where ammonia is removed by a downward stream of water from a sprinkler. Generally, there are two scrubbers, weak ammoniacal liquor being used in the first and water in the second. The ammoniacal liquor is pumped to a still where, under the action of steam and lime, ammonia gas is given off. This passes into sulphuric acid in the saturators, sulphate of ammonia separates out, and is dried in a centrifugal dryer. The Wilton sulphate plant is in use at Bargoed, the sulphate being automatically discharged from the saturator into the drying machine.

The direct system of sulphate manufacture is replacing the old method in the newly-built plant. In the Otto-Hilgenstock system the hot gases are drawn through two tar sprays, which remove the tar before any ammoniacal liquor condenses. The gases then pass into saturators. No cooling water is wanted, no ammoniacal liquor is produced, and no lime or steam is required. In the absence of scrubbers, &c., the total space occupied is relatively small.

Yield of By-products.—On account of the nature of the coal used, the yield of by-products is smaller than in most districts:—

Product.	Yield per Ton of Coal.		
	South Wales.	Yorkshire.	Average for United Kingdom.
Tar	1·5—2·5%	5%	4%
Sulphate	18—20lbs.	22—35lbs.	24lbs.
Gas	8,000—10,000 c.ft.	10,000—11,500 c.ft.	10,000 c.ft.

A few particulars are here given of the method of coking adopted by most of the South Wales makers:—

Name.	Locality.	Type of Oven.
Blaenavon Co.	Blaenavon	Welsh Rectangular. Otto-Hilgenstock*
Cardiff Collieries Co.	Llanbradach	Otto-Hilgenstock.
Ebbw Vale Steel, Iron and Coal Co.	Ebbw Vale and Cwm.	Welsh Rectangular. Coppée.
Elders Collieries	Maesteg	Coppée.
Gt. Western Colliery Co.	Pontypridd	Coppée: Otto-Hilgenstock.
Guest, Keen, & Nettlefolds	Dowlais: Cwmbran	Rectangular: Coppée.
Lancaster's Steam Coal Co. (Russell's coke)	Cwmtillery	Coppée by-product.
Lewis Merthyr Collieries Co.	Hafod	Simplex.
North's Navigation Collieries	Maesteg: Tondu	Coppée.
Powell Duffryn Co.	Bargoed	Coppée: Koppers.
Pyman Watson & Co. (Ffaldau coke)	Pontycymmer	Coppée.
Rhymney Iron Co.	Rhymney	Coppée.
Tredegar Iron and Coal Co.	Tredegar	Coppée.
Welsh Navigation Co.	Coedely	Coppée by-product.*

* In construction.

Output.—Owing to the number of additional coking plants that have been built lately, the total output of coke from the

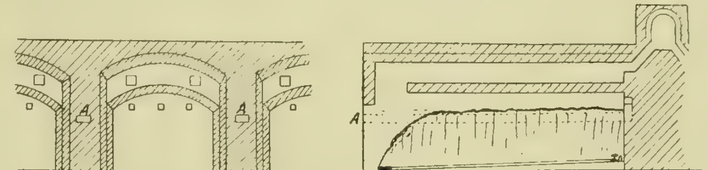


FIG. 3.—COX'S OVEN.
Length, 15ft.; breadth, 5ft. 9in.; height (total), 6ft. 6in.; height to jack arch, 4ft. 6in.

coalfield is now largely in excess of what it was 10 or even five years ago. The figures for 1910 were:—

	Tons.
Glamorgan	792,144
Monmouth	575,473
Total for South Wales	1,367,617
Total for United Kingdom	11,925,115

Including Denbigh, where there are 61 Semet-Solvay ovens.

The chief market for South Wales coke is, of course, the ironworks of the district. The large ironworks make coke for their own consumption in addition to what they purchase. A large and increasing amount is sent to the Midlands—to Staffordshire and the Birmingham district—and, although on account of railway rates it cannot compete with Durham coke in the Northern coalfield, there are regular consumers of South Wales coke beyond the Scottish border. The effect of increased production is already shown in the exports, and it is probable that South Wales will take a much more important position as a coke exporter in the future. Export of coke began in 1856 with 5,000 tons; it now amounts to about 160,000 tons per annum, the greater part going to Spain (Huelva), the Argentine and Uruguay, the Eastern Mediterranean, and Cape Colony.

Character of Coke.—In conclusion, the analyses of a number of Welsh cokes are given. Commercially, they are classified as

"Special Foundry," "Foundry," and "Furnace" cokes. These correspond roughly to the following types:—

Class of Coke.	Volatile matter.	Ash.	Sulphur.	Phos-phorus.	Fixed Carbon.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Special foundry	0·5	5·8	0·6	0·02	93·7
Foundry	0·8	7·5	0·8	0·02	91·7
Furnace..................	0·8	10·0	1·1	0·02	89·2

The best Welsh coke is unsurpassed in physical condition. Its pores are small and finely divided, and in purity and freedom from deleterious substances it compares favourably with other cokes; it has proved itself eminently suited for foundry work.

Coke.	Moisture, per Cent.	Ash, per Cent.	Sulphur, per Cent.	Phosphorus, per Cent.	Authority.	Remarks.
Blaenavon	4·0	9·5	0·81	0·020		Average at ovens.
,, ...	2·0	7·8	0·75	0·019	G. Foster Martin ...	Average for 3 months at furnaces.
Cwmbran	4·0	11·0	1·5	0·020	Jenkins	Average at blastfurnaces.
Ebbw Vale	5·0	7·5	0·7	0·020	Selway Browne ...	Average at ovens.
Ffaldau	4·0	5·7	0·58	0·016	Jenkins	Average at blastfurnaces.
,, ...	—	4·98	0·69	0·016	F. G. Treharne ...	
Great Western	—	5·97	0·77	0·022	,, ...	
,, ...	3·0	6·5	0·80	0·020	T. G. Watts	Average for 3 months at ovens.
,, ...	1·0	5·8	0·65	0·017	,, ...	Best quality.
,, ...	4·0	7·6	0·78	0·024	Jenkins	Average at blastfurnaces.
Lewis-Merthyr	1·0	7·5	0·68	0·023	E. C. Evans	Average at ovens.
Newport Abercarn	4·0	10·0	1·1	0·095	Jenkins	Average at blastfurnaces.
,, ...	—	7·76	0·63	—	E. Riley	
Norths	—	5·0	0·55	—	J. Boyd Harvey ...	Average at ovens.
,, Maesteg	4·0	5·6	0·62	0·017	Jenkins	Average at blastfurnaces.
,, Tondu	4·0	6·0	0·68	0·019	,, ...	,, ,,
Powell Duffryn...	6·0	9·0	1·10	0·040	,, ...	,, ,,
,, ...	4·0	7·84	0·91	—	E. M. Hann	Average at ovens.
Rhymney	5·0	10·5	1·25	0·047	Jenkins	Average at blastfurnaces.
Tredegar...	6·0	8·0	0·90	0·040	,, ...	,, ,,

MELTING POINTS OF CHEMICAL ELEMENTS.

THE accompanying interesting table giving the melting points of chemical elements is reproduced from a circular recently issued by the U.S. Bureau of Standards. The value of the melting points used by the bureau as standard temperatures for the calibration of thermometers and pyrometers are indicated in capitals. The other values have been assigned after a careful survey of all the available data. As nearly as may be, all values, in particular the standard points, have been reduced to a common scale, the thermodynamic scale. For high temperatures and for use with optical pyrometers, this scale is satisfied very exactly by taking $C_2 = 14{,}500$ in the formula for Wien's law connecting I, monochromatic luminous intensity of wave length λ, and T absolute temperature:

$$\log I/I_1 = C_2 \lambda \log e\, (I/T_1 - I/T)$$

For all purposes, except the most accurate investigations, the thermodynamic scale is identical with any of the gas scales.

Melting Points of Chemical Elements.

Element.	F.	C.	Element.	F.	C.	Element.	F.	C.
Helium..........	< −456	< −271	CADMIUM........	609.6	320.9	Cobalt............	2714	1490
Hydrogen........	−434	−259	LEAD............	621.1	327.4	Chromium..........	2750	1510
Neon............	−423	−253?	ZINC............	786.9	419.4	IRON..............	2768	1520
Fluorine........	−369	−223	Tellurium.......	846	452	PALLADIUM	2820	1549
Oxygen..........	−360	−218	ANTIMONY.......	1166	630.0	Zirconium.........	3100	1700?
Nitrogen........	−346	−210	Cerium..........	1184	640	Thorium...........	>3090 <Pt.	>1700 <Pt.
Argon...........	−306	−188	Magnesium.......	1204	651	Vanadium..........	3150	1730?
Krypton.........	−272	−169	ALUMINUM	1217.7	658.7	PLATINUM.........	3191	1755
Xenon...........	−220	−140	Calcium.........	1490	810	Beryllium.........	>3270	>1800?
Chlorine........	−150.5	−101.5	Lanthanum.......	1490	810?	Ytterbium.........	....	?
MERCURY........	− 37.7	− 38.7	Strontium.......	....	>Ca<Ba?	Titanium..........	3450	1900?
Bromine.........	+ 18.9	− 7.3	Neodymium.......	1544	840?	Rhodium...........	3525	1940
Cæsium..........	79	26	Arsenic.........	1560	850?	Ruthenium.........	>3550	>1950
Gallium.........	86	30	Barium..........	1560	850	Columbium (Niobium)........	4000	2200?
Rubidium........	100	38	Praseodymium....	1725	940?	Boron.............	4000–4500	2200–2500
Phosphorus......	111.4	44	Germanium.......	1756	958	Iridium...........	4170	2300?
Potassium.......	144	62.3	SILVER..........	1761	960.5	Uranium...........	....	?
Sodium..........	207.5	97.5	Glucinum........	....	>Ag	Molybdenum........	4500	2500?
Iodine..........	236.5	113.5	Radium..........	....	?	Osmium............	4900	2700?
Sulphur.........	S_I 235.0 S_{II} 246.6 S_{III} 224.2	112.8 119.2 106.8	GOLD............	1945.5	1063.0	Tantalum..........	5160	2850
Indium..........	311	155	COPPER..........	1981.5	1083.0	TUNGSTEN.........	5430	3000
Lithium.........	367	186	Manganese.......	2237	1225	Carbon............	>6500 for p = 1 At.	>3600 for p = 1 At.
Selenium........	422–428	217–220	Yttrium.........	....	?			
TIN.............	449.4	231.9	Samarium........	2370–2550	1300–1400			
Bismuth.........	520	271	Scandium........	....	?			
Thallium........	576	302	Silicon.........	2588	1420			
			NICKEL..........	2646	1452			

Railway Accidents in 1911.—The general report to the Board of Trade on railway accidents which occurred in the United Kingdom during 1911 just issued shows that the total route length of the railways at the end of 1911 was 23,417 miles, while the total number of miles travelled by trains was 428,000,000, an increase of more than five millions on the previous year. The quantity of minerals and general merchandise conveyed was 5,235,000,000 tons, an increase of over nine millions. The total number killed in 1911 was 1,070, and there were 8,345 injured. The corresponding figures for the previous year were 1,062 and 8,342, showing an increase of eight killed and three injured in 1911. The average number of killed for the period 1900-1909 was 1,115, and of injured 7,249.

ELECTRICAL NOMENCLATURE.

We present herewith a schedule of electrical terms, with definitions, which has been issued by the British Electrotechnical Committee of the International Electrochemical Commission. The schedule has been prepared by a sub-committee on nomenclature, comprising Mr. A. P. Trotter (chairman); Messrs. S. Z. De Ferranti, W. Duddell, F.R.S., Robert Hammond, R. W. Hammond, H. W. Miller, F. H. Nalder, Dr. A. Russell, A. Siemens, Dr. S. P. Thompson, F.R.S., C. H. Wordingham, and P. F. Rowell (secretary).

Absolute.—A system of magnitudes is said to be absolute when all the magnitudes of the system can be defined in terms of units adopted as fundamental.

An instrument for absolute measurements is one which can be standardised by means of measurements which involve only the fundamental units.

Admittance.—The reciprocal of impedance. The quotient obtained by dividing the current in a conductor by the electromotive force which produces it.

Alternation.—A term not recommended. A half period. (*See* Period and Frequency.)

Antenna.—A conductor or system of conductors for the emission or reception of Hertzian waves.

Balancer.—A motor generator or accumulator used to equalise differences of potential between the different wires of a multiple-wire system.

Ballistic.—An instrument in which the period of the moving part is long compared with the time of the duration of the transient force which the instrument is intended to measure.

Bifilar Suspension.—The suspension of the moving part of an instrument by two threads, so arranged that the restoring force is mainly produced by gravity.

Bow.—A bow-shaped appliance for effecting a sliding connection between an overhead conductor and an electrically-propelled vehicle.

Carcel.—The name of a standard oil lamp, the official standard of candle-power used in France.

Characteristic.—A curve or graph representing the relations between two magnitudes, which characterise the behaviour of an apparatus—*e.g.*, the exciting current of a dynamo and the electromotive force generated.

Charge.—(*a*) Of a conductor. The total quantity of electricity on it. (*b*) Of an accumulator. (*See* Accumulator.) (*c*) Of a condenser. (*See* Condenser.) Verb to charge.—The operation by which any apparatus receives a quantity of electricity, part of the whole of which it returns on discharge.

Coercive Force.—The magnetic force required to annul the residual magnetism of a substance.

Coil.—One or more turns of a conductor wound side by side in one or more layers.

Condenser.—An apparatus consisting of two conducting surfaces separated by a dielectric.

Conductance.—The conductance of a conductor is the quotient of the current by the potential difference between the terminals of the conductor, usually expressed in Mhos.

Conductivity.—The conductivity (specific conductance) of a substance is measured by the current which flows parallel to an edge through a unit cube of the substance, when unit difference of potential is maintained between the two faces perpendicular to that edge. The reciprocal is resistivity.

Conductor.—A body or substance which permits the passage of electricity.

Counter Electromotive Force, or Back-electromotive Force.—An electromotive force which opposes the flow of the current in the circuit.

Decohere.—To restore a coherer to its original state of resistance.

Delta.—A mode of connection in three-phase alternating-current working, in which three windings or apparatus are so connected that they may be diagrammatically represented by a triangle. A particular form of mesh.

Diamagnetic.—A substance having a magnetic permeability less than that of a vacuum (unity).

Direct Current.—A term not recommended. (*See* Continuous current.)

Discharge.—(*a*) Of a condenser: An operation which tends to bring the two conducting surfaces of a condenser to the same potential. (*b*) Of an accumulator: An operation which tends to bring the two plates of an accumulator to the same potential and which permits the chemical energy to be reconverted into electrical energy, and utilised in an outside circuit.

Disruptive Discharge.—The breaking down of a dielectric under electrical stress, accompanied by sparking.

Eddy Current.—A current induced in a conducting body either by a varying magnetic field or by the body moving relatively to a fixed magnetic field.

Efficiency.—(1) In case of generators, motors, converters, or transformers: The ratio of the total output to the total input. (For instance, in case of a separately excited synchronous generator the excitation power should be added to the power received at the shaft.) (2) In case of accumulators: (*a*) The ratio of the amount of energy available during the discharge to the amount of energy required during the charge (watt-hours.) (*b*) The ratio of the amount of current available during the discharge to the amount of current required during the charge (ampere-hours).

Electrometer.—An instrument which utilises electrostatic forces for the measurement or comparison of differences of potential.

Extra Current.—An obsolete term. The current during the variable period on closing or opening an inductive circuit.

Extra High Pressure.—(*See* Pressure.)

Factor of Safety.—In mechanics, the ratio of the ultimate breaking stress to the maximum normal working stress.

Farad.—In the practical system of units the farad is the unit of electrical capacity. It is inconveniently large, and therefore capacities are usually expressed in microfarads.

Fault.—Any local defect in the insulation or continuity of a conductor which may interfere with its use.

Feeder.—A conductor for conveying electrical energy from the place where generated or transformed to feeding-points or sub-stations. Feeders are not used for supplying consumers directly, owing to the varying pressure along their length.

Feeder Box or Pillar.—A box or pillar which may contain switches, links, or fuses for connecting feeders with distributing networks.

Feeder, Negative.—(*See* Return Feeder.)

Feeding Point.—The junction of a feeder with the network.

Ferro-Magnetic.—A substance whose permeability is greater than that of a vacuum (unity.) (*See* Paramagnetic.)

Field, Electromagnetic.—(*See* Field, Magnetic.)

Field, Electrostatic.—Any region in which there are electric lines of force, as in the space between a positively charged and a negatively charged surface.

Field Magnet.—Any permanent magnet or electromagnet employed for the purpose of providing a magnetic field. (It is incorrect to speak of the field magnets of a dynamo or motor as its fields; they should be called its magnets, if the term field magnets is too long.)

Field, Magnetic.—Any region in which there are magnetic lines of force, as in the space between or surrounding the poles of a magnet or within a magnetising coil. The strength of the field is usually expressed in C.G.S. measure as the number of lines per square centimetre. One line per square centimetre is called a gauss. (*See* Line and Maxwell.)

Figure of Merit, of a Galvanometer.—(*a*) The deflection in millimetres per micro-ampere at a scale distance of 1 metre when reduced to a period of 10 seconds and a resistance of 1 ohm. (*b*) The current in amperes required to produce a deflection of 1 millimetre at a scale distance of 1 metre. Sometimes expressed as the number of megohms through which 1 volt will give that deflection. Of a telegraph instrument.—The minimum current necessary to work the instrument with absolute certainty.

Flame Arc.—An arc in which the major portion of the light is given by the flame instead of by the electrodes.

Flashing.—(*a*) Any process of manufacture involving the

temporary electrical overheating of a glow lamp filament. (*b*) The coating of a glow lamp filament with a layer of carbon by heating it electrically in a hydro-carbon vapour.

Flashing Over.—The temporary formation of an arc from brush to brush on a commutator.

Flash Test.—The momentary application of a high electrical pressure between two conductors insulated from each other.

Flux.—(*a*) Magnetic: The number of lines of magnetic induction which pass round a magnetic circuit. (*See* Induction.) (*b*) Photometric: The whole luminous radiation of a beam of light, or the candle-power multiplied by the solid angle of the beam. (*c*) Chemical: Material used for reducing or dissolving the oxides of molten metals in casting, soldering, brazing, &c.

Foot Candle.—The illumination produced by a source of 1 candle-power falling perpendicularly on a surface at a distance of 1ft. from the source.

Form-Factor.—The ratio of the effective value to the mean value of a periodic function.

Fourth Rail.—(*See* Conductor Rail.)

Friction Loss.—Loss due to mechanical friction exclusive of windage.

Frog.—In tramway overhead work. A fitting uniting two diverging trolley wires with a single wire (*a*) provided with a spring tongue, or (*b*) of the fixed type.

Fuse.—The actual wire or strip of metal in a cut-out which is fused by an excessive current.

Galvanometer.—An instrument for measuring small electric currents.

Gap, Air, Magnetic.—Any air space in a magnetic circuit.

Gap, Spark.—Any break in the continuity of a metallic conductor so arranged as to permit of an electrical discharge across the break.

Gauge.—(*a*) A general term applied to various kinds of measuring instruments. (*b*) The thickness of a plate, or the diameter of a wire, on the inch, millimetre, or on any arbitrary scale. (*c*) The distance between the rails of a railway or of a tramway. In the case of a railway it is the distance between the inner sides of the heads of the rails. In the case of a tramway it is the distance between the inside edges of the tread of the rails—*i.e.*, over and including the grooves.

Gauss.—A name given to the absolute electromagnetic unit of magnetic induction in the C.G.S. system. (*See* Field, Magnetic and Line.)

Generating Set.—The combination of a generator and a prime-mover.

Glow Discharge.—A silent discharge of electricity through a gas which causes the gas to have a uniformly luminous appearance or glow, and which does not volatilise the electrodes.

Glow Lamp.—A lamp in which the filament or wire is caused by the current to glow or incandesce. A term recommended instead of incandescent lamp in order to avoid confusion with the incandescent gas mantle.

Gramme Calorie.—(*See* Calorie.)

Great Calorie.—(*See* Calorie.)

Grid.—In an accumulator: The framework supporting the active material.

Ground.—A term used in America having the same meaning as earth.

Henry.—The practical unit of the coefficient of self-induction or of mutual induction in the electro-magnetic system.

High Pressure.—(*See* Pressure.)

High Tension.—Obsolete term for high pressure.

Homopolar, Dynamo, or Motor.—A dynamo or motor in which the inductive action takes place in a magnetic field or a series of magnetic fields without change of sign.

Homopolar Induction.—A term sometimes applied to the induction which occurs when a conductor is moved through a magnetic field, so as to cut the lines of force in the same direction continuously. Sometimes called unipolar.

Horse-Power.—The industrial unit of power. The British horse-power is equivalent to 33,000 foot-pounds per minute or (approximately) 746 watts.

Hot Wire Instrument.—An instrument, the indication of which depends on the expansion of a wire or wires through which flows an electric current.

Hysteresis.—The lagging of the strain behind the stress, which when the material is taken round a complete cycle and brought back to the initial state, involves a dissipation of energy.

Hysteresis, Magnetic.—The tendency by which changes of magnetism lag behind the changes of magnetic force which cause them.

Impedance.—The ratio of the electromotive force to the current which is produced by it in a conductor. The term is used with varying or alternating currents.

Incandescent Lamp.—(*See* Glow Lamp.)

I.H.P.—Abbreviation for indicated horse power.

Inductance.—(*a*) Synonym for coefficient of self-induction. (*b*) The reaction due to self-induction. (*See* Reactance.)

Induction.—When an electric or a magnetic force acts, through the ether, upon a body so as to alter its electric or magnetic state, that alteration of state is said to be induced in it, as distinguished from alterations of state communicated to it by conduction or contact. The operation of inducing alteration of state is called induction. The three chief induced actions are (*a*) induced electrostatic charge, (*b*) induced magnetism, (*c*) induced electromotive force.

Induction, Electrostatic.—When a body is brought into an electric field, thereby causing an electric charge or charges to appear on the body, these charges are called induced charges; and the operation is called electrostatic induction.

Induction, Magnetic.—When a mass of iron, &c., is brought into a magnetic field, thereby causing magnetic poles to appear on the mass, these poles are called induced poles, and the magnetism so acquired is called induced magnetism; and the operation is called magnetic induction. (The magnetic lines of force so imparted to the mass of iron, &c., are called magnetic lines of induction.)

Induction, Magneto-electric.—When a body is subjected to the action of a varying magnetic field, thereby causing electromotive force to be generated in the body, these electromotive forces are called induced electromotive forces; and any currents that result in the body are called induced currents; and the operation of thus inducing electromotive forces and currents is called magneto-electric induction.

Induction Motor.—An alternating-current motor in which the secondary part receives its current by magneto-electric induction and not by conduction.

Induction, Mutual.—The (magneto-electric) induction exercised between two circuits, whereby the variations of the current in one circuit generate electromotive forces in the other circuit is called mutual induction. This mutual relation may be quantitatively expressed by means of a coefficient of mutual induction.

Induction, Mutual, the Coefficient of.—(M) is the sum of the effective linkages of the turns of one circuit (the secondary) with the flux due to unit current in the other circuit (the primary.)

Induction, Self.—The (magneto-electric) induction exercised upon the turns of a circuit by the current in itself is called self induction. In may be quantitatively expressed by means of a coefficient of self-induction.

Induction, Self, the Coefficient of.—(L) is the sum of the linkages of flux and current when the current in the coil is unity. The (total) self-induction of any coil is the product of its coefficient of self-induction and the current it is carrying.

Induction, Unipolar.—(*See* Homopolar.)

Inductive Capacity, Specific.—(*See* Capacity.)

Inductive Circuit.—A circuit in which the self-induction at the working frequency or at make or break is appreciable compared with its resistance.

Inductive Load.—An output at a power factor which by reason of self-induction is less than unity.

Inductive Resistance.—A resistance having appreciable self-induction.

Inductor Generator.—A generator with stationary field and stationary armature coils, and in which masses of iron or

inductors by moving past the coils alter the magnetic flux through them.

Inductors.—In Inductor Generators: The masses of iron employed to effect variations of the magnetic flux passing through the armature coils.

Input.—The total power received at the shaft or terminals of a machine or apparatus.

Insulate (v.a.).—To surround or support a conductor by non-conducting bodies or materials so as to restrict the flow of electricity to the desired path.

Insulator.—(*a*) Any material which does not appreciably conduct electricity. (*b*) An appliance used to insulate and usually to support a conductor.

Integrating Meter.—A meter which sums up or integrates the quantity to be measured, with reference to time.

Intermediate.—The intermediate or neutral middle wire or wires of a three-wire or multiple-wire system.

Intensity.—There is an increasing disposition to restrict the use of the word intensity in English physical science to a ratio, the denominator being an area. The older meaning was synonymous with strength.

Intensity of Current.—An obsolete expression. It has been replaced by strength of current.

Intensity of Field, Magnetic.—(*See* Magnetic Field.)

Intensity of Light.—The illuminating power or candle-power of a source of light.

Intensity of Magnetisation.—The magnetic moment per cubic centimetre.

Interrupter.—Sometimes called break. A mechanism or device used to break the primary circuit of an induction coil.

Ion.—An ion is a charged atom or molecule, or a group of atoms or molecules carrying a charge.

Joule.—A unit of heat equivalent to 0·24 = calorie, or one watt-second.

Joule Effect.—The heating in a conductor by the passage of an electric current through it, and due to the resistance of the conductor.

Kathion.—The ion which is carried to the kathode.

Kathode.—(*a*) In an electrolytic cell: The conductor through the surface of which the current leaves the electrolyte. (*b*) In a primary cell: The conductor (generally carbon) through which the current leaves the electrolyte. (*c*) The electrode by which the current leaves a cell or other apparatus, such as a vacuum tube.

Keeper, of Magnet.—An iron bar for completing the magnetic circuit (usually of a permanent magnet). (*See* Armature.)

Kelvin.—A term officially proposed and authorised by the Board of Trade, May, 1892, but which has not come into common use, for a kilowatt-hour.

Key.—An appliance consisting essentially of a lever carrying a contact or contacts, generally used in signalling and in testing.

Kicking Coil.—Name given to a choking coil used in conjunction with lightning arresters.

Kilowatt.—A unit of power. One thousand watts. Equivalent to 1·34 British horse-power (approximately).

K.V.A.—Contraction for kilo-volt-ampere, or 1,000 volt-amperes.

K.W.—Contraction for kilo-watt.

Lag.—The interval of time or angle by which one event follows another. (*See* Phase Difference.)

Lagging Current.—An alternating current, the phase of which is retarded in time relatively to the impressed electromotive force.

Lamination.—The division of a mass of material into thin sheets either to prevent eddy currents or to give flexibility. The thin sheets or stampings of iron forming part of a magnetic circuit are often called the laminations.

Lay, in a Cable.—The pitch or length parallel to the axis of one complete turn in the spiral arrangement of a stranded cable may be expressed (*a*) as a multiple of the diameter of the layer considered; or (*b*) as the increase in length of a strand above the length of the cable, expressed as a percentage of the length.

Lead.—(*a*) Of a conductor or pipe: Its direction or run. (*b*) Sometimes used as a synonym for a conductor. (*c*) Of an alternating quantity: The interval of time or angle by which one event precedes another. (*See* Phase Difference.)

Leading Current. An alternating current, the phase of which is in advance in time relatively to the impressed electromotive force.

Leakage.—(*a*) The passage of electricity from one conductor to another or to earth, caused by want of perfect insulation. (*b*) Magnetic: That part of the magnetic flux which does not follow the path provided for it.

Leakance.—The reciprocal of insulation resistance.

Leyden Jar.—A condenser in the form of a jar, generally of glass, having a conducting surface inside and out.

Lightning Arrester.—An appliance for protecting electrical apparatus by providing an alternative discharge path.

Limiter.—A device for giving warning when a predetermined current is exceeded.

Line, Telegraphic.—That part of a telegraph, telephone, or railway signalling circuit, whether aerial, underground, or submarine, which does not include the controlling or operating apparatus and the source of power. Used also, collectively, for a group of wires, including poles, pipes, junction boxes, &c.

Lines of Force.—(1) A line such that the tangent to it at any point represents the direction of the force acting at that point. (2) Magnetic: A line such that the tangent to it at any point represents the direction of the magnetic force at that point. By convention the magnitude of the magnetic force at any point is represented by supposing as many magnetic lines of force to be drawn through one square centimetre (situated around the point) as there would be dynes exerted on unit pole if placed at that point. Unit intensity, *i.e.*, one dyne per unit pole, or one line per square centimetre, is called one gauss. (*See* Magnetic Flux.) (3) Electrostatic: A line such that the tangent to it at any point represents the direction of the electric force at that point. By convention the magnitude of the electric force at any point is represented by supposing as many electrostatic lines of force to be drawn through one square centimetre (situated around the point) as there would be dynes exerted on one unit of positive electricity placed at that point.

Link.—A readily removable conductor forming part of a circuit, generally in the form of a flat bar.

Linked Switches.—Switches linked together mechanically so as to operate simultaneously.

Load.—(*a*) Synonym for output. (*b*) Synonym for weight.

Loaded.—Telegaph line or cable: A line or cable of which the self-induction has been intentionally increased.

Load Factor.—The number obtained by dividing the actual output of a generator or of a whole generating station during a given period by the output if the maximum had been maintained during that period.

Loop Test.—A method of testing employed to locate a fault in a telegraph or other conductor when it can be arranged to form part of a closed circuit.

Looping In.—Bringing a wire as a loop to and from a terminal to avoid making a T joint.

Loss, Total.—The difference between output and input.

Low Tension.—Obsolete term for low voltage.

Magnet Coil, Magnetising Coil.—The winding used to magnetise an electromagnet such as the field magnet of a dynamo, sometimes called field coil.

Magnet, Permanent.—A body which, having been magnetised retails its magnetisation.

Magnet Winding.—A set of magnet coils.

Magnetic Blow-out.—An apparatus so arranged as to produce a magnetic field which breaks the arc formed on opening the circuit.

Magnetic Flux.—The number of magnetic lines which pass through any area is called the flux through that area. In the case of a closed magnetic circuit, the number obtained by multiplying magneto-motive force by reluctance. Unit, one line or Maxwell.

Magnetic Flux Density.—The number of magnetic lines per square centimetre. The number obtained by dividing magnetic force by permeability. Sometimes called the induction, a term not recommended in this sense.

Magnetic Force.—The force at any point in a magnetic field experienced by a unit pole placed at that point, sometimes called field intensity or strength of field. (At any point in a closed magnetic circuit, the magneto-motive force at that point.) (In a closed magnetic circuit, the magneto-motive force per unit length.)

Magnetic Permeability.—Magnetic conductivity or specific permeance compared with vacuum. The number obtained by dividing magnetic flux density in a substance by magnetic force.

Magnetic Permeance.—Sometimes called magnetic conductance. The number obtained by dividing magnetic flux by magneto-motive force.

Magnetic Reluctance.—The reciprocal of magnetic permeance (sometimes called magnetic resistance, a term not recommended).

Magnetic Reluctivity.—Specific magnetic reluctance. The reciprocal of permeability of a substance.

Magnetic Remanence.—Residual flux density after the magnetic force has been removed.

Magnetic Susceptibility, or Magnetisability.—The number obtained by dividing magnetic intensity by magnetic force.

Magnetisability.—(*See* Magnetic Susceptibility.)

Magnetisation.—(1) The process or the result of communicating magnetism to a body. (2) The (intensity of the) magnetic moment per unit of volume of a magnet.

Magnetise.—To give a body the properties of a magnet.

Magneto.—Contraction for magneto-electric generator. A generator whose field magnets are permanent magnets.

Magnetometer.—An instrument for measuring magnetic force.

Magnetomotive Force. — That which causes or tends to cause a magnetic flux. The unit is $4\pi/10 \times$ ampere turns. The industrial unit is the ampere turn.

Main.—Any conductor forming part of a distributing network. The principal conductors are collectively called the mains. (*See* Feeder and Trunk Main.)

Maxwell.—The name given to the magnetic line of force or unit of magnetic flux.

Mesh.—A mode of connection in polyphase alternating-current working, in which the windings or apparatus are so connected that they may be diagrammatically represented by a closed figure.

(*To be continued.*)

TESTS OF CURTIS TURBINES.

In the course of the discussion on the paper on "The Present State of Development of Large Steam Turbines," by Prof. A. G. Christie, read before the American Society of Mechanical Engineers, and reproduced recently in our columns, Mr. W. L. R. Emmet stated that injustice is done to the Curtis type of turbine in Table II. appearing in the paper and given on page 669 of our issue of May 31st last. The first machine mentioned in this table is a 2,000-kw. Curtis-Parsons operating at 1,500 revs. per minute and is reported to give an efficiency of 71·8 per cent. with a moderate degree of superheat. Mr. Emmet states that anyone familiar with the design of either Curtis or Parsons machines knows perfectly well that no such result has ever been produced under such conditions. The efficiencies assigned to the five General Electric-Curtis machines mentioned range from 63·6 per cent. down to 61 per cent. The first, which operates at 3,464 kw., is a representative result of the machine in question and is a good performance when the very high vacuum used is considered. Of the other four, only one of the tests is representative when the machine is correctly tested and in good condition, and in that case, also, the extremely high vacuum is the cause of a relatively low efficiency.

In discussing this table, the author states in paragraph 70: "It is therefore apparent that the efficiency ratio alone will express in the best manner the degree to which the designer has approached ideal results in his turbine." To this statement Mr. Emmet takes exception, for the reason that it is naturally possible to produce higher efficiencies in turbine construction with moderate degrees of vacuum than it is with very high degrees of vacuum, the limitations to the effective use of high vacuum being many and their extent being affected by speed and capacity. Therefore the designer who produces a relatively low efficiency with a very high vacuum may have accomplished his purpose much more creditably than another who has produced a higher efficiency with a low vacuum.

Tests of Representative Curtis Turbines.

Customer.	Date of Test.	Load, Kw.	R.p.m.	Steam Pressure Absolute.	Superheat Deg. Fah.	Vacuum.	Water Rate, Lbs. per Kw.-Hr.	Efficiency, Per Cent.
		7,526	720	184·40	134	28·65	13·732	66·6
Boston Edison Co.	1907	7,481	720	185·10	129	28·58	13·866	66·6
Commonwealth Edison Co., Chicago	1907	12,000	750	200·00	125	28·00	14·220	66·2
Boston Edison Co.	1912	12,460	720	207·50	191	27·52	13·630	68·2
Stock	1911	4,000	1,800	189·00	0	28·00	16·050	64·3
Louisville Ltg. Co.	1911	6,500	1,800	180·00	100	28·00	14·780	66·10
British Thomson-Houston, Rugby (maker)	1912	2,000	3,000	165·00	150	28·00	14·400	67·3

None of the General Electric machines referred to in Prof. Christie's tabulation, except the first mentioned, was designed later than 1904, while many of the other makes are of very recent production. The accompanying table gives tests of a few representative Curtis machines. The first two tests apply to machines in Boston, very carefully and repeatedly tested when they were comparatively new. These machines are of the same date and type as most of those to which the figures in Prof. Christie's tabulation purport to apply, and are representative of the original large 5-stage vertical units when correctly tested and in good condition. These tests were made with very perfect facilities by the Boston Edison Company's engineers. The third test applies to an 8,000-kw. machine in Chicago of the same date and type. One of the tests in Prof. Christie's paper also purports to refer to this machine under different conditions. The next three items refer to recent 6-stage Curtis machines, and the last refers to a 3-stage Curtis machine recently produced by the British Thomson-Houston Company. This latter machine produces a very remarkable result when its small capacity and extreme simplicity are taken into consideration.

The accurate testing of steam units is, Mr. Emmet states, a matter which requires great care and is susceptible of many kinds of error. Many figures concerning such tests which are entirely incorrect are being constantly circulated. It is only by comparison of many tests and careful observance of consistency as to results and characteristics that one can ever be sure as to turbine economies. The figures given in the table herewith have been analysed and compared and are unquestionably correct. It will be observed that they give an impression concerning the value of Curtis turbines which is very different from that produced by Prof. Christie's tabulation.

METAL QUOTATIONS.

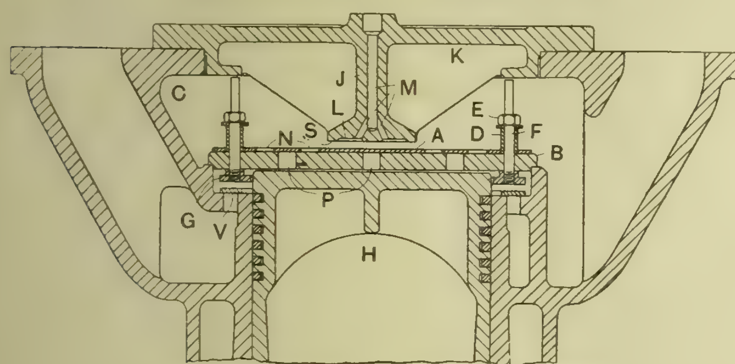
TUESDAY, AUGUST 27TH.

Aluminium ingot	80/- per cwt.
„ wire, according to sizes, &c. ......from	102/- „
„ sheets „ „ ...... „	120/- „
Antimony .... £28/-/- to	£29/-/- per ton.
Brass, rolled	8½d. per lb.
„ tubes (brazed)	11½d. „
„ „ (solid drawn)	9¾d. „
„ „ wire	8⅝d. „
Copper, Standard	£79/12/6 per ton.
Iron, Cleveland	62/9 „
„ Scotch	68/9 „
Lead, English	£20/10/- „
„ Foreign (soft)	£20/7/6 „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£7/15/- per bottle
Silver	28⅜d. per oz.
Spelter	£26/10/- per ton.
Tin, block	£210/10/- „
Tin plates	14/7½ „
Zinc sheets (Silesian)	£29/10/- „
„ (Stettin; Vieille Montagne)	£29/17/6 „

DUNLOP'S DELIVERY VALVE FOR AIR COMPRESSORS.

AN improved design of delivery valve for air compressors of the type in which the output is controlled by holding open the delivery valve at times when no air is required to be compressed is shown in the accompanying sectional view. As heretofore constructed, the delivery valve is of cylindrical formation and is adapted to slide in a correspondingly shaped guide from which the air can be exhausted in such manner as to ensure that the valve will be held open. A delivery valve of this type is heavy, considering the small area of the discharge opening thereof, and is not suitable for adaptation to high-speed compressors.

In the design illustrated, the invention of Mr. James Dunlop, 69, Armadale Street, Dennistoun, Glasgow, the delivery valve comprises a comparatively thin disc A, which rests normally on a perforated seat B in the valve chest C of the compressor, being adapted to be guided by means of pins or projections which are fixed in relation to the valve A and its seat B. As shown, the valve A is guided by means of bushes



DUNLOP'S DELIVERY VALVE FOR AIR COMPRESSORS.

D, which are fixed in relation to the valve and its seat by means of nuts E on pins F passing through the bushes and threaded into an annular ring G which is shown surrounding the piston H of the compressor and serving as a guard ring or stop for the ring-shaped inlet valve V. The lift of the valve A is limited by a flat face S on an inwardly projecting member J, secured to the valve chest cover K, which face is provided with grooves L so formed that when the valve A engages with the face S it cuts off communication between the valve chest C and grooves L. In communication with these grooves, and with passages M connected therewith, is a pipe (not shown) leading to the atmosphere, this pipe having a stop cock or valve which, on being opened, permits the compressed air in the grooves L to be exhausted, whereby the disc A constituting the delivery valve is held against the grooved face S, thereby controlling the output of the compressor. In order that the lift of the delivery valve will be as small as possible, the valve is perforated, the perforations N being arranged in zig-zag fashion in relation to the perforations P in the valve seat, the discharge past the valve A being effected through the perforations N as well as at the edge of the valve.

STEAM-BOILER EFFICIENCY.*

BY EDWARD A. UEHLING.

FIFTY years ago a steam engine that consumed less than 40lbs. of steam per horse-power hour was quite an exception. Twenty-five years ago 30lbs. was accepted as good practice. To-day a steam consumption above 20lbs. is considered unsatisfactory, and in exceptional cases a steam consumption as low as 10lbs. per horse-power hour has been reached.

The best average boiler efficiency fifty years ago was probably close on to 60 per cent.; twenty-five years ago it was about 60 per cent., and to-day the average boiler efficiency still hangs close to 60 per cent. Thus while the steam engine has been so improved that a given amount of steam will produce nearly three times the power obtainable fifty years ago, the steam boiler continues to waste 40 per cent. of the heat energy contained in the fuel. There are several reasons why this is so:—

To begin with, the steam boiler (including its setting), because of the simplicity of its function, had been developed into a far more perfect apparatus for the purpose of generating steam fifty years ago than was the steam engine of that time. Later, however, thorough investigations of the properties of steam were carried on by scientists, who formulated the laws of expansion, thereby not only revealing the great wastefulness of the then existing steam engine, but at the same time pointing out the upper limits possible to attain. Based on these revelations of science, inventive genius and mechanical skill, in combination with practical experience, wrought the great improvements embodied in the many types of engines of to-day, including the steam turbine.

The principal reason for the slow progress in the economical operation of the steam boiler is due largely to the fact that it is of necessity a rough and uncouth apparatus, placed in dirty, dingy surroundings, generally indifferent, and often inadequately housed. Brawn and muscle are considered the principal requirements in a boiler attendant. As a rule, neither compensation nor environment is calculated to attract the more intelligent from among the men available, and perhaps there is not one fireman in a thousand who has any conception of the chemical reactions that constitute the process of combustion.

The steam engine, on the other hand, is a highly finished machine, housed in well-lighted and well-appointed quarters; therefore commanding and receiving close attention. Furthermore, it is attended by high-class men, trained by education and long experience, who understand its mechanism and mode of operation. Again, in the steam engine, although it is a complex mechanism as compared with the steam boiler, the regulations and adjustments necessary to maintain maximum efficiency are exceedingly simple in comparison with what is required to attain and maintain the highest boiler efficiency.

A steam engine correctly designed and properly constructed, accurately adjusted and adapted to the work to be performed, will give maximum economy. The speed is uniform, and the steam used is automatically regulated to suit the load. Certain definitely fixed and automatic adjustments have been found to give maximum efficiency; the attendant has only to maintain these adjustments to ensure efficiency.

The efficiency of the steam generator depends on far more complex conditions, many of which are not only beyond control, but are continually changing. Some of them are atmospheric conditions, quality of the fuel and the condition of the boiler as to setting, dirty heating surface, air infiltration, draught, &c. The grates become choked with slate and clinker, obstructing the air passages and causing irregular flow, resulting in a deficiency of air in one place and an excess in another. Every one of these variables affects the efficiency of the boiler furnace. Furthermore, the required output, which varies in some plants between very wide limits, is an important factor. One is therefore forced to the conclusion that the lack of progress in boiler efficiency under actual operating conditions is not due to any want of improvements in design and construction of the present-day boiler and setting, though much remains to be desired, but that it is due almost entirely to insufficient knowledge of the conditions involved and consequent wasteful manipulation.

That this is true is proved by the fact that almost invariably official boiler tests, made by or under the direct supervision of experts, show from 10 to 20 per cent. greater efficiency than is obtained from the same boilers in every-day practice. This raises the question: Can the high efficiency obtained by an expert be at least approximately maintained in every-day practice? If so, how can it be accomplished? What does the expert do to get his results?

He analyses the coal for the purpose of ascertaining its heat value, and to find out how to burn it effectively. He brings with him one or more expert firemen, or selects the best available from the existing staff, and generally pays them extra to ensure good work. He makes sure that the boiler is clean, inside and out, that the grate bars are whole and straight and suitable for the kind of coal to be burned. He sees to it that there are no cracks and crevices in the boiler wells, and that the cleaning doors close tight.

He is also assisted by a staff of trained observers. One keeps a careful record of the weight of coal fired; another accurately weighs or measures the feed water; a third analyses the flue gas and notes its temperature; while the

* Abstract of paper read before the American Master Mechanics' Association.

fourth ascertains the quality of the steam. Many other data are noted and recorded, all of which are necessary to enable the expert to calculate the efficiency of the boiler under test and to strike a heat balance. But with the exception of those appertaining to the composition and temperature of the flue gas, none of the data noted and recorded by the staff of assistants is of the least aid in attaining high efficiency. And since the two essential elements in the flue-gas records, CO_2 and temperature, can be autographically recorded and continuously indicated by appliances readily available at reasonable cost, an expert and a corps of assistants are not required to assure economic boiler operation in every-day practice.

Sifting the essentials from the non-essentials in the programme of the expert boiler tester, there are: (1) Clean boilers; (2) tight settings; (3) skilful firing; (4) knowledge of the chemical composition and physical properties of the coal used; (5) furnace adapted to the fuel; (6) draught regulation; (7) continuous knowledge of the percentage of CO_2 contained in the flue gas, also its temperature at the point where it leaves the boiler.

The first five of these conditions essential to boiler efficiency should be quite self-evident.

1. As to clean boilers, it should not require the services of an expert to keep the boilers clean, yet a great deal of coal is wasted because of dirty and scaly heating surfaces.

2. Tight boiler settings are the exception rather than the rule. Should an expert and a staff of assistants be required to keep the settings tight? Certainly not. It is nevertheless a deplorable fact that air infiltration is one of the most prolific causes of low boiler efficiency.

3. Every material change in the chemical and physical property of the coal requires a change in the method of firing, the frequency of cleaning the fire, the strength of draught, &c.; a correct knowledge of the chemical composition and physical properties of coal used will, therefore, be of material assistance in maintaining high efficiency in every-day practice.

4. Regarding the furnace and grate bars, every steam engineer of experience knows that they must be adapted to the kind of coal available if good results are to be realised. It may and generally does require the services of a combustion expert to determine the grate and furnace construction best adapted to burning a given fuel; but when these conditions are once established there is no good reason why they should not be maintained.

5. Draught regulation is one of the most important factors, and is probably the least understood. Draught, whether natural, forced, or induced, is manifested by a difference in pressure. The effective draught is the difference in pressure between the air under the grate bars and that at the point of leaving the boiler. It may be considered as divided into two parts, namely, the furnace draught and the boiler draught. The former is the pressure difference between the ashpit and the furnace, and the latter is the pressure difference between the furnace and the uptake. The boiler draught varies directly with the volume of gas coming from the furnace; hence for the same rate of combustion it varies inversely as the percentage of CO_2 in the flue gas, and for the same percentage of CO_2 it varies directly as the rate of combustion.

The furnace draught depends on many things: the kind of coal, the rate of driving, the thickness of the fire, and its condition, the formation of clinker, &c., from all of which it is evident that the proper regulation of the draught requires close and intelligent observation and judgment.

6. Skilful firing and intelligent manipulation are therefore prime requisites in the economic operation of steam boilers, and that is why the expert, when he is conducting an efficiency test, is so particular in selecting his firemen. To overcome any errors in judgment on the part of the firemen, he resorts to analysing the flue gases, which is the only correct and adequate method of controlling the process of combustion.

Maximum efficiency results when the necessary amount of fuel is completely burned with a minimum excess of air, and the flue gases leave the boiler with the lowest temperature consistent with the rate of driving. Without adequate means of knowing when this condition obtains, it is impossible for even the most expert fireman to maintain maximum efficiency. Combustion experts when conducting efficiency tests generally determine the percentage of CO_2, CO, and O; but for every-day practice it is necessary only to know the percentage of CO_2 and the temperature of the flue gas to be able to tell whether the boiler is being operated economically or wastefully, and to what extent heat is going to waste up the chimney. Not less than 90 per cent. of the avoidable heat losses in the operation of steam boilers is due to excessive air supply, and since the percentage of CO_2 in the flue gas is a correct index of the excess of air it contains, an instrument that will continuously indicate and record this constituent is a most important if not an absolutely necessary factor in attaining and maintaining maximum boiler efficiency.

A continuous record of the temperature of the escaping flue gas, although less valuable for controlling the boiler operation, is nevertheless of great importance. The temperature when recorded simultaneously with the CO_2 will give most valuable information as to the condition and operation of a boiler. The temperature of the flue gases is but slightly affected by excess of air supplied to the furnace; hence cannot be directly controlled by the fireman. This depends on the ratio of the heating surface of the boiler to the grate area, on the condition of the heating surface, and on the rate of driving; also, the stack temperature is markedly affected by air infiltration, while an excess of air supplied to the furnace affects the stack temperature but slightly. Thus it is seen that while the stack temperature alone may give very misleading information, in conjunction with a determination of the CO_2, very valuable information is had about the condition of the boiler itself as well as the boiler setting.

A draught gauge applied to the furnace shows the resistance through the ashpit door, the grates, the ashbed, and the fire. With a given effective draught, if the ashpit doors are partially closed the furnace draught is increased, but the rate of combustion is decreased. The same effect is produced by the accumulation of ashes, the formation of clinker, and the caking of the coal. The furnace draught is thus increased by at least four distinct causes, all of which tend to check the rate of combustion. On the other hand, if the fire is sliced, the furnace draught is decreased and combustion is increased, and still more is this the case of the fire is cleaned. It is clear, then, that the readings of a draught gauge in the furnace cannot be relied upon as an index to the rate of driving, much less to economical operation.

From the foregoing it would appear, first, that the chimney draught is affected favourably by wasteful boiler operation, due to high stack temperature, and unfavourably by wasteful operation, due to a low percentage of CO_2 in the flue gas; but that a knowledge of the chimney draught and temperature is of great value as a check on economic operation of a boiler plant; second, that the effective draught upon which depends the rate of combustion is itself dependent on the variable conditions of the furnace, that it cannot be relied on as a guide by which to regulate combustion; third, that furnace draught due to the ever-changing conditions must necessarily vary if a definite rate of combustion is to be maintained, and is therefore useless as a guide, but is of the greatest value as an index to the condition of the furnace, provided there is a true index to the rate of combustion. Fortunately such an index can be made available.

From what has been said in the foregoing, it should appear evident that in order to attain and maintain high boiler efficiency it is necessary to employ scientific means for the purpose of gaining the information necessary to economical operation.

Sixth International Congress for Testing Materials.—The sixth congress of the International Association for Testing Materials will be held at New York, from September 2nd to 7th. The president is Prof. Henry M. Howe, of Columbia University, New York; the Congress Secretary is Mr. H. F. J. Porter, of 1, Madison Avenue, New York. The meetings will be held in the Engineering Societies' Building, 29, West 39th Street, New York. The Congress will be opened on the evening of Monday, September 2nd, when the American Society for Testing Materials will receive members, joined by the American Societies of Mechanical Engineers and of Electrical Engineers, and by the Institute of Mining Engineers. Sectional meetings for the reading and discussion of papers will be held on Tuesday, September 3rd, to Saturday, September 7th.

DETERIORATION AND SPONTANEOUS HEATING OF COAL IN STORAGE.*

BY HORACE C. PORTER AND F. K. OVITZ.

COAL-STORAGE problems have grown in importance with the increasing consumption of coal and the consequent greater need of guarding against interruptions of supply by strikes or transportation difficulties. Owing to the large number of requests that are being received by the Bureau of Mines for exact information on the deterioration and spontaneous heating of coal, this preliminary paper is published as a brief summary of the results thus far obtained in the Bureau's investigation. A complete account is being prepared for publication as a bulletin of this Bureau.

Not many years ago coal was commonly regarded as an extremely unstable material, subject to serious alteration and losses on exposure to the elements. In 1907 a German gas-works engineer† claimed to have found that moist fine coal sustained an average heating value loss of 1·7 per cent. per week by the escape of gas. Other statements like these are to be found in recent literature, but probably the great majority of chemists and engineers to-day hold no such exaggerated ideas on the deterioration of coal in storage. There is, however, a well-defined suspicion in the minds of many that the loss of volatile matter by coal and the deterioration by oxidation are large enough to be of industrial importance, and the object of the investigations described in this paper was to determine accurately the extent of the deterioration in different types of coal.

A study of the loss of volatile matter from crushed coal during storage was made in the laboratory of the Bureau of Mines. The coal tested was in 20lb. samples, which represented a variety of types from widely separated fields. Each sample had been broken to about half-inch size in the mine, and as quickly as possible placed in a large glass bottle for dispatch to the laboratory. At the laboratory the accumulated gas was withdrawn and the volatile products were permitted to escape freely and continuously at atmospheric pressure and temperature. The results of these experiments have already been published. Suffice it to say that although several coals evolve methane in large volumes, especially in the early period after mining, the coals tested lost in one year from this cause only 0·16 per cent. at most of their calorific value. It seems, therefore, that the loss caused by escape of volatile matter from coal has been greatly overestimated.

More elaborate tests were undertaken to determine the total loss possible in high-grade coal by weathering. The extent of the saving to be accomplished by water submergence as compared with the open-air storage was to be settled, as was also the question whether salt water possessed any peculiar advantage or disadvantage over fresh water for this purpose. As an instance of the claims made for the advantage of salt-water submergence there may be cited an article by Mr. J. Macaulay, of Newport, who reports that coal accidentally sunk in the salt mud of the English Channel actually had its calorific value improved 1·8 per cent. by 10 years' submergence.

In the brief outline, the tests by the Bureau were carried out as follows: Four kinds of coal were chosen—New River, W. Va., on account of its large use by the Navy; Pocahontas, Va., from its wide use as a steaming and coking coal, and from its being the principal fuel used in the Panama Canal work; Pittsburg coal, as a rich coking and gas coal, and Sheridan, Wyo., sub-bituminous coal or "black lignite" as a type much used in the West. In the test with the New River coal, 50lb. portions were made up out of one large lot which had been crushed to ¼in. size and well mixed, and these portions, confined in perforated wooden boxes, were submerged under sea water at three naval yards that differed widely from one another in climatic conditions. Portions of 300lbs. each from the same original lot were exposed to the open air, both outdoors and indoors, at the same naval yards.

A test of the Pocahontas coal was made at only one point, the Isthmus of Panama, where coal was placed in a 120-ton pile exposed to the weather. Pittsburg coal was stored at Ann Arbor, Mich., both in open 5-ton bins outdoors and in 300lb. barrels submerged in fresh water. The Wyoming sub-bituminous coal was stored at Sheridan, Wyo., both as run-of-mine and slack, in outdoor bins that held 3 to 6 tons each.

A fact the authors wish to emphasize is that no test was made for any physical deterioration of the coal, such as an increase of friability, or a slacking of lumps. Consequently the results do not show how the relative availability of heat units may have been affected by physical changes; but they do show how much the calorific value, as determined in the laboratory, was affected by storage of the coal under the several conditions.

The moisture, ash, and sulphur contents and the calorific value of each sample were determined. A Mahler bomb calorimeter and a carefully calibrated Beckmann thermometer were used in the calorimetric work, and except for the Sheridan, Wyo., tests, all this work was done by the same man.

The results show in the case of the New River coal a loss of less than 1 per cent. of calorific value in one year by weathering in the open. In two years the greatest loss was at Key West, 1·85 per cent. There was practically no loss at all in the submerged samples in one year, fresh or salt water serving equally well to "preserve the virtues" of the coal. There was almost no slacking of lumps in the run-of-mine samples. In all tests the crushed coal deteriorated more rapidly than the run-of-mine. The Pocahontas run-of-mine coal in a 120-ton pile on the Isthmus of Panama lost during one year's outdoor weathering less than 0·4 per cent. of its heating value, and showed little slacking of lumps. Gas coal during one year's outdoor exposure suffered practically no loss of calorific value measurable by the calorimetric method used, not even in the coal forming the top 6in. layer in the bins. The Wyoming coal in one of the bins deteriorated in heat value 5·3 per cent. during storage for two and three-fourths years, and more than 2·5 per cent. in the first three months. There was bad slacking and crumbling of the lumps on the surface of the piles, but even where this surface was fully exposed to the weather the slacking did not penetrate more than 12 to 18in. in the 2¾-year period.

Storage under water unquestionably preserves the heating value and the physical strength of coal. But such storage practically makes necessary the firing of wet coal, and consequently the evaporation in the furnace of added moisture varying in amount from 1 to 15 per cent., according to the kind of coal. This factor is an important drawback to the underwater storage of coals which mechanically retain 5 to 15 per cent. of water after draining. In the case of high-grade coals, however, if firemen are permitted, as is frequently the case, to wet down their coal before firing, in order, as some say, "to make a hotter fire," the addition during storage of the 2 or 3 per cent. of moisture which these coals retain becomes of little consequence. Submerged storage is an absolute preventive of spontaneous combustion, and on that account alone it may be justified when the coal is particularly dangerous to store and when large quantities are to be stored; but unless the storage period is to be longer than one year, there seems to be no ground for storing any coal under water merely for the sake of the saving in calorific value to be obtained by the avoidance of weathering.

Losses of value from spontaneous heating are a much more serious matter than the deterioration of coal at ordinary temperatures. Oxidation proceeds more rapidly as the temperature rises. The oxidation, beginning at ordinary temperatures, attacking the surfaces of particles, and developing heat, is probably, in some degree, an absorption of oxygen by the unsaturated chemical compounds in the coal substance. In a small pile of coal this slowly-developed heat can be readily dissipated by convection and radiation, and very little rise in temperature results. If the dissipation of the heat is restricted, however, as in a large pile densely packed, the temperature within the pile rises continuously. The rate of oxidation of the coal plotted against the temperature makes a curve that rises with great rapidity. When the storage conditions are such as to allow warming of the coal to a temperature of about 100° C., the rate of oxidation becomes so great that the heat developed in a given time ordinarily exceeds the heat dissipated, and the temperature rises until, if the air supply is adequate, the coal takes fire. Evidently, therefore, it is important to guard against even moderate heating of the coal, either spontaneous or from an external

* A preliminary report of the United States Bureau of Mines.

† Hannack F., "Stahl und Eisen."

source. Increased loss of volatile matter and of heating value occurs with a moderate rise of temperature, even though the ignition point is not reached.

Spontaneous combustion is brought about by slow oxidation in an air supply sufficient to support oxidation, but insufficient to carry away all the heat formed. The area of surface exposed to oxidation by a given mass of any one coal determines largely the amount of oxidation that takes place in the mass; it depends on the size of the particles and increases rapidly as the fineness approaches that of dust. Dust is therefore dangerous, particularly if it is mixed with lump coal of such a size that the interstices permit the flow of a moderate amount of air to the interior. Coals differ widely in friability, that is, in the proportion of dust that is produced under like conditions. This variation in friability is a factor in affecting the liability to spontaneous heating. Ideal conditions for such heating are offered by a mixture of lump and fine coal, such as run-of-mine with a large percentage of dust, piled so that a small supply of air is admitted to the interior of the pile.

High volatile matter does not of itself increase the liability of coal to spontaneous heating. A letter of enquiry sent by the Bureau to more than 2,000 large coal consumers brought 1,200 replies. Of the replies, 260 reported instances of spontaneous combustion. The result shows no falling behind of the "smokeless" type of coal in furnishing instances of spontaneous combustion, and no cause for placing especial confidence in this type of coal for safety in storage.

In the large stock piles at Panama, coals with 17 to 21 per cent. volatile matter give a great deal of trouble from spontaneous fires. Moreover, several large works report that their low-volatile coals are more troublesome in respect to spontaneous fires than their high-volatile gas coals. Strange as it may seem, the oxygen content of coal appears to bear a direct relation to the avidity with which coal absorbs oxygen; high oxygen coals absorb oxygen readily, and therefore have a marked tendency to spontaneous combustion.

The effect of moisture and the effect of sulphur on the spontaneous heating of coal are questions on which there has been a great deal of discussion and much difference of opinion. Very little experimental evidence has been brought to bear on either of the questions, and certainly neither is as yet settled. Richters has shown that in the laboratory dry coal oxidises more rapidly than moist; but the weight of opinion among practical users of coal is that moisture promotes spontaneous heating. In not one of the many cases of spontaneous combustion observed by the authors could it be proved that moisture had been a factor. Still the physical effects of moisture on fine coal, such as closer packing together of dust or small pieces, may in many cases aid spontaneous heating.

Sulphur has been shown to have only a minor effect in most instances. On a number of occasions samples of coal from the places in a pile or bin where the heat was greatest have been analysed, both for the total sulphur and for that in the sulphate or oxidised form. The difference between the two determinations—or, in other words, the unoxidised sulphur—was in no case less than 75 per cent. of the average total sulphur in the coal which had not been heated. In other words, not more than one-fourth of the total sulphur had entered into the heat-producing reaction. The possibility remains, of course, that the sulphur-bearing material that oxidised was concentrated in a pocket, possibly as moist, finely divided pyrites, and by its concentration and, perhaps, by its comparatively rapid oxidation sufficient heat was developed in that spot to act as an igniter. Such an explanation, however, is not plausible when judged by the many analyses of coal subjected to spontaneous heating.

Freshly mined coal and the fresh surfaces exposed by crushing lumps exhibit a remarkable avidity for oxygen, but after a time the surfaces become coated with oxidised material, "seasoned," as it were, so that the action of the air becomes much less vigorous. In practice, coal that has been stored for six weeks or two months and has even become already somewhat heated, if rehandled and thoroughly cooled by the air, seldom heats spontaneously again.

With full appreciation of the fact that any or all of the following suggested precautions may prove impracticable or unreasonably expensive under certain conditions, they are offered as advisable for safety in storing bituminous coal. (1) Do not pile over 12ft. deep, nor so that any point in the interior of a pile will be over 10ft. from an air-cooled surface. (2) If possible, store only screened lump coal. (3) Keep out dust as much as possible; to this end reduce handling to a minimum. (4) Pile so that lump and fine are distributed as evenly as possible; not, as is often done, allowing lumps to roll down from the peak and form air passages at the bottom of the pile. (5) Rehandle and screen after two months, if practicable. (6) Do not store near external sources of heat, even though the heat transmitted be moderate. (7) Allow six week's "seasoning" after mining and before storing. (8) Avoid alternate wetting and drying. (9) Avoid admission of air to interior of pile through interstices around foreign objects, such as timbers or irregular brickwork, or through porous bottoms, such as coarse cinders. (10) Do not try to ventilate by pipes, or more harm may often be done than good.

THE VALUE OF SAWMILL REFUSE AS FUEL IN GAS PRODUCERS.*

BY CHAS. E. SNYPP.

I WILL endeavour to state briefly my experience in the firing of the following fuels in gas producers, namely, bituminous coal, anthracite, coke and coke braize, and sawmill refuse.

Our producer plant was installed for the purpose of burning Pittsburg bituminous coal, guaranteed to furnish gas of about 125 B.T.U. to the engines. As a matter of fact, we operated the plant continuously for about four years on various kinds of coal. The producer we used was a pressure type Wood producer. The capacity of the producer plant was 840 h.p., consisting of a combination of three units, each having a producer shell 8ft. in diameter by 12ft. high with steam-jacketed top; one wet scrubber 5ft. high by 18ft. high; one dry scrubber 8ft. in diameter by 3ft. high; one pressure fan; one gas-holder, and one motor-driven mechanical tar extractor.

The coal was locked in through an air-tight hopper into each of the producer shells. When the workmen poked the fires, the gases under pressure from the blast escaped freely through the poke holes, causing great distress to the workmen. To overcome this difficulty we installed a fan between the dry scrubber and the tar extractor, intending to bring the producer shells under a slight vacuum. This relieved the men of the gases and yet retained our pressure in the holder, thus forcing the gases to our engines under pressure. I will state that this fan was too small to completely accomplish the purposes intended, though it did materially reduce the quantity of gas escaping from the poke holes, thus relieving the workmen.

After the producer gases are formed they pass into the wet scrubber, which is an enclosed tower of slats, wherein the water passes in a downward direction and the gases pass upward. The gases are then conducted to a centrifugal mechanical tar extractor which removes most of the tar, and then to a dry scrubber, which is a shell about 8ft. diam. and packed with excelsior in layers. The gases then pass through an exhaust fan to the holder and thence to the engines.

The first coal that we burned was Pittsburg bituminous coal, but we found that while this fuel filled the requirements as far as the richness of the gas was concerned, our plant went out of commission at regular intervals in consequence of tar congestion. These intervals came closer and closer together the longer we operated the plant on this coal, on account of greater and greater accumulation of its peculiar tar. In fact, the tar was too heavy for the centrifugal tar extractor, and breakdowns of this machine were frequent. This led us to try other bituminous coals with the idea of reducing the tar nuisance.

After four years of continuous service of the producer plant on various bituminous coals we found that in spite of our selection the whole system of pipes and engines was becoming congested with tar. We also found that it was quite an expensive repair to remove this tar from the engine cylinder rings. In fact, many of the rings had to be cut from the grooves with a cold chisel. We found that a gas plant could not be run for more than five hours on gases

* Paper read before the Louisiana Engineering Society, May 13th, 1912, and reproduced from the "Journal of the Association of Engineering Societies."

from Pittsburg bituminous coals without taking out these tars, as the valves and piston rings would stick. Alabama coals did not do much better.

These Alabama coals were analysed particularly for fixed carbon and volatile matter in order to select those with a high fixed carbon and a low volatile matter. They gave greater satisfaction because of the reduced quantity of tar, and at the same time furnished a gas that was just as rich as the Pittsburg bituminous, namely, about 125 B.T.U. The Alabama coal, however, introduced a trouble peculiar to itself, which finally forced us to abandon it. The first trouble was that the fuel came to hand of irregular quality, even from the same mine, particularly as to volatile matter and ash. The content of ash was especially unsatisfactory and very irregular, varying from $6\frac{1}{2}$ to 11 per cent. Not only was the content of ash high, but it had the peculiar property of fusing in the producer or forming a solid clinker, which was almost impossible to penetrate with poke bars, and even after penetration with bars and sledges was not brittle enough to break in pieces of a size that could be readily removed from the producer itself. Besides this, the act of fusing cuts off the air from the fuel beds, producing a lean gas, or one low in British thermal units, finally putting that particular producer out of business.

We next resorted to the experiment of burning anthracite coal. Our experiment was limited to a few tons, but the conclusion reached was that we could not produce a gas high enough in heat value. The best condition did not yield much more than 100 B.T.U. in the gas. Besides, this fuel was too expensive. The next experiment was to substitute coke and coke braize for anthracite. This furnished a fair quality of about 110 B.T.U. gas in the beginning, but we experienced great difficulty in the producers filling up with ash, and the ash fusing, thus causing cavities which could not be poked out. The quality of the gas sometimes fell as low as 80 B.T.U., thus putting the plant out of commission. When this happened we would have to cool down and sledge the clinkers. I noticed that when the gas became lean we could raise the heat value of the gas by feeding the producer with barrel staves, which would keep us running.

During this interval numerous improvements on the producer plant were made, as follows: First, the "Z" pipe which conducts the gases from the producer shell to the wet scrubber would frequently become clogged with dry soot, and we found that on account of the bends in the pipe this soot would bake in hard clinkers, thus reducing and eventually choking the pipe. This pipe was replaced by a horizontal pipe extending between the producer shells and the wet scrubber, and a partition was run vertically in the wet scrubber, thus making a downtake which opened directly into the bottom of the wet scrubber.

Second, we found that tar was accumulating in the bottom of the wet scrubber and was very difficult to remove. The metal bottom was replaced by a water seal, extending all over the bottom of the wet scrubber. All other pipes where the gases have a downward trend and a sharp bend were similarly provided with water seals, in order that the tar might readily drop out and wash out, thus facilitating the cleansing of the producer.

While these water seals or water bottoms are essential to the cleansing of the plant, the following little experience will show that they must be used with some judgment. The wet scrubber as installed in the ordinary-sized machine is about 5ft. diam. The metal bottom of this scrubber was removed, as I have just stated, and a water seal substituted, which proved to be just the thing for a pressure producer. However, I was called upon some months later to go to a plant where they were having trouble with their producer. Upon my arrival I was surprised to see how nicely the producer was working, and noticed that the installation consisted of 140 h.p. engine together with a corresponding size producer of the suction type. In spite of no apparent difficulty, everybody seemed to be afraid to approach this producer, and the superintendent told me to wait awhile and see what would happen. I did wait awhile and noticed that the engine was drawing gas under a head of about 3in. of water, and this was gradually increasing until some hours afterwards it reached 5in., and then ran rapidly to 10in. Then there was a terrific explosion which blew through the seal and blew the poke hole castings and the plugs from the top of the producer. The negro stoker happened to be on top handling a wheelbarrow of coal, and he must have been a new hand or a nervous one, as the last I saw of him was that he was tumbling towards the ground with the wheelbarrow of coal, a distance of about 15ft., and I noted particularly that he landed on his feet and ran down the hillside. The only reason that I did not leave was that I was penned in by a guard rail. The after-effect of this explosion was that the remaining water seal was alternately drawn in and expelled by numerous puffs that followed. It was apparent to me at once that what had really happened was that the engine had drawn up the water from the seal and admitted a large influx of air, which no doubt made the proper mixture for causing an explosion. The remedy applied was very simple. The opening on the water seal under the scrubber was restricted in size so that no great quantity of water could be drawn in suddenly. The plant ran along afterwards without any trouble whatever, with simply working the beds and removing the clinker when the draught became obstructed.

On account of these various troubles and because of the increase in heating value of producing gases made with barrel staves referred to before, I was prompted to try sawmill refuse in the producers, and found very much to my satisfaction that we were able to operate the plant continuously on about 130 B.T.U. to 135 B.T.U. gas, and the plant was more reliable on account of the even quality of gas. After about a month of use of this refuse fuel our tar troubles began to disappear, and now, after using this fuel for a couple of years, it is a very rare occurrence to have an inlet valve or an exhaust valve stick in the engines on account of tar, or carbon deposits. In fact, we have discarded the dry scrubber altogether, and we even operated one week without a tar extractor at all, on account of that machine needing repair. This illustrates how well the sawmill refuse has solved the problem in our case when it is recalled that we could not run even five hours on coal without removing the tar.

The refuse that we use is known as "cypress hog." It consists of about 50 per cent. of sawdust and 50 per cent. of chips, such as are discharged from the "hog," which is a machine used by sawmills to destroy their refuse. This material runs from 30 to 55 per cent. moisture, and this moisture seems to be necessary for best working conditions. I will state that we have to guard against the sawdust blowing over into the pipes which conduct the gases to the wet scrubber. This is probably a local trouble, due, no doubt, to the strength of the blast that we use in order to get capacity. We have been able to realise full capacity using sawmill refuse, and our engines deliver a brake horse-power on about $4\frac{1}{2}$lbs. of this fuel.

The changes necessary to fire sawmill refuse are merely the removing of the coal dump hoppers and substituting a hollow cylinder about 10ft. high slightly tapered and made larger at the bottom and fitted with a slide gate at both top and bottom; these slides are worked with levers, and the sawmill refuse is locked into the producers through these tubes.

To start firing a producer with sawmill refuse it is not necessary to have an underlying bed of cinders or ash to cover the blast pipe. The fuel can be dumped in on the water seal and fire can be started either on top or through the side poke holes. Aside from these conditions, the beds seem to be subject to all conditions prevalent in the firing of coal. A clinker is formed of a brittle nature and can be easily removed with the fine ash. The percentage of ash is so small that a producer can be operated about three weeks before removing the ash.

Cavities and chimneys will burn in the bed, and eternal vigilance and poking are necessary to produce a uniform quality of gas. In order to lessen the labour of poking it is good practice to feed occasionally, say, once a day or when the quality of the gas fluctuates, one or two charges of blocks ranging in size from stove lengths to 15in. diam. These blocks will find their way into the cavities and stop the chimneys, and the producer will respond instantly. I have had cavities form low down in the beds and cause

trouble, but we have always succeeded in poking down overlying fuel and closing this cavity.

We also experimented with "pine hog," and we find that it is more efficient fuel for producer gas than "cypress hog." An average of ten analyses made on gas produced from "pine hog" showed 161·4 effective B.T.U. against 130 to 135 for cypress. The reason for this is probably due to the greater heat value of pine itself as compared with cypress. The analyses of heating value of these two fuels showed that the cypress was 5,540 B.T.U., while pine was 7,605 B.T.U. These are on fuel as received, and, therefore, include moisture. The only reason that we do not use pine is that cypress is more available as far as our plant is concerned, which means that it is cheaper, comparatively speaking, although it is pound for pound a much richer fuel.

I have added below a number of analyses of gas produced from various kinds of fuel that it has been my lot to experiment with in solving our problem.

Kind of Fuel.	No. of Analyses.	Effective B.T.U.	Co_2.
Pittsburg bituminous	15	125·3	9·6
Alabama bituminous	12	112·2	7·8
Pocahontas coke	10	103·1	—
Nut coal	3	100·4	10·5
Coke braize	4	108·0	6·4
Anthracite coal	39	91·2	12·4
Cypress hog	12	134·2	10·3
Cypress hog and petroleum...	7	133·2	—
Pine hog	11	161·4	9·9

To summarise: the advantages to be derived from burning sawmill refuse where it is available are as follows: (1) Little ash, therefore little cleaning to be done. (2) High-grade gas, *i.e.*, gas of higher heat value as compared with other fuels in our type of producer. (3) A lesser quantity of tar, and much more limpid in character. (4) Gas of constant quality with less labour. (5) No deadly gases to overcome the workmen. (6) And finally, the all-important factor of lower cost per horse-power hour must not be forgotten.

In conclusion, I wish to explain that there is no intention on my part of casting any reflection on the producer or the original installation that we had. I believe that we were among the first to burn bituminous coal in our section, and our work was of such character that the producer plant had to be operated 24 hours a day and sometimes on Sunday.

Cost of cypress waste fuel (basis 4½lbs. per horse-power hour at 50c. per ton) equals	0·1125c. per h.p. hour.
Cost of firing 4½lbs.	0·1125c.
Total cost per horse-power hour for cypress waste	0·2250c.
Cost of Pittsburg bituminous coal (basis 1·5lbs. per horse-power hour at $4.10 per ton) equals	0·3075c. per h.p. hour.
Cost of firing 1·5lbs. of Pittsburg bituminous coal	0·0750c.
Total cost per horse-power hour for Pittsburg bituminous coal	0·3825c.
Cost of Alabama bituminous coal (basis 1·5lbs. per horse-power hour at $2.75 per ton) equals	0·2062c. per h.p. hour.
Cost of firing 1·5lbs. of Alabama bituminous coal	0·0750c.
Total cost per horse-power hour for Alabama bituminous coal...	0·2812c.

RECENT DEVELOPMENTS IN THE ELECTRICAL ART.*

BY PROF. ELIHU THOMSON.

I APPRECIATE very highly the honour done me in the award of the Elliott Cresson Medal, and return my sincere thanks for the recognition accorded me. It may not be known to all present that my work in the electrical field virtually began within these walls, and in this hall. As a very youthful member of the Institute it was my privilege to take an active part in its work, beginning nearly 40 years ago. Appointed to deliver a course of five lectures on electricity early in 1877, in this very hall, I am happy to recall that the members were good to the youthful and untried lecturer, and filled the hall each evening. Serving with Prof. E. J. Houston and others on its Committee on Dynamo Electric Machines in the winter of 1877 and 1878, we were able to secure, for the first time, scientific data, voltage, resistance, current, illumination, efficiency, &c., on several dynamos for arc lighting and the single arc light which they each furnished. The report of the committee appeared in the "Journal" in 1878. When I left Philadelphia to go to New England in 1880 I had served on the Board of Managers of the Institute for some years. It is, then, with a peculiar sense of gratitude and satisfaction that I receive this recognition of my work.

I have been asked to address you on this occasion on "Recent Developments in the Electrical Art." The applications of electricity now cover such a wide field that even to give a fair list of them would be a tax on your patience. Moreover, the term "recent" admits of great latitude, as the whole art is indeed recent. I shall use the word in a somewhat more restricted sense. But before referring to any recent advances I hope I may be pardoned for recalling, on this occasion, a few incidents besides those to which I have already alluded. My prime object in the course of five lectures given by me in this hall thirty-five years ago was to show that electricity from any source was in essence the same, and so help to break down the barriers then existing in many minds between static electricity, dynamic, voltaic, thermo, and magneto electricities. Not to enter into details, I may state that at one of the lectures, in preparing my apparatus in this hall to show that static or high-tension electricity could be converted into dynamic or low-tension currents, the result of the experiment first suggested the possibility and method of my latter invention of electric welding.

In the fall of 1878 I built a special dynamo, and a laborious piece of work it was for a foot lathe. It was used in conjunction with Pro. Houston in lectures and demonstrations before the Institute. In fact, the machine was first tested and operated in this hall. It was in some respects a unique machine, being either a self-acting, alternating-current dynamo or a direct-current machine at will. As an alternator its winding made it 2-phase or bi-phase. Its voltage, by coupling its windings, could be varied in the ratio of 1, 2, and 4. Its field could be similarly varied, so as to increase the range of variation, and it required 3 or 4 h.p. to drive it. In this hall, and along with this machine, transformation with induction coils was experimented with. Such coils are now called transformers. This was in January and February, 1879. It may be interesting to note that, probably for the first time in the art, two transformers were used with their finer wire primaries connected in parallel to the dynamo line, while the coarse wire secondaries at lowered voltage supplied the work current. This is the arrangement now so extensively used in practice. It was here, also, and at about the same time, I received my first heavy electric shock from an induction coil steeping up the current of the dynamo to about 10,000 volts. The convulsion threw me back and drew the wires from my hands. The accident certainly taught caution.

The working of this early dynamo was indeed the means of forming business affiliations which latter led to developing the Thomson-Houston arc lighting system, on which the large business of the Thomson-Houston Company, at Lynn, Mass., was later built. This company having extended its business into railways, motors, incandescent lighting, &c., it was consolidated together with the Edison General Company, into the General Electric Company, in 1891.

In the early years of the art there was so much unknown that highly important discoveries and inventions followed each other at close intervals. Nowadays this is not to be expected. The technical progress of to-day consists largely in the refining of methods, increasing efficiencies, improving construction, reducing costs, and extending the ranges of use into new fields, while providing for the rapid growth of the industry in lighting, power transmission in all its varied phases, railways, electric heating and furnaces, electro-chemistry, and metallurgy.

Still, these later years are not without their technical triumphs in discovery and invention. The Edison carbon fila-

* Address presented at a meeting of the Franklin Institute, May 15th, 1912, when Prof. Thomson received the Institute's Elliott Cresson Medal.

ment lamp, the influence of which on the growth of industrial electricity has been stupendous, was not known till the close of 1879. Improved in minor details, it remained for upwards of a quarter of a century without a rival for small units of light; the improvement coming by the substitution of tantalum and then of pure tungsten for the carbon; the gain in efficiency with the latter was such that approximately one-third of the energy would give as much light, and of a whiter and better quality. Tungsten had long been known in an impure state and in its compounds, and it was used as a component of special steels. Pure tungsten, as at first produced, was found to be a hard, glossy, brittle metal, absolutely without ductility of malleability in the cold, yet by careful research and persistent effort methods were found which at last yielded wire which could be drawn cold.

This was done in the research laboratory at Schenectady, and drawn tungsten wire filaments are now the standard. The unyielding brittle metal has been made so tractable that a single length of over three miles of wire, of a diameter less than that of a human hair, has been drawn. Tungsten drawn wire has the extraordinary strength of 600,000lbs. to the square inch of section. Ductile tungsten is now found to be superior to platinum for electric contacts, and far less expensive. It is also the ideal material for the targets of Rontgen-ray tubes, not yielding where platinum would be melted rapidly in forcing the tube for the purpose of shortening the time of exposure in radiography.

Has the tungsten lamp reached the limit of its development? Certainly not. The knowledge gained in the past year or two renders probable a further advance in efficiency of lamps; leading to the confident expectation that more than 50 lamps of 20 c.p. each may be obtained from an expenditure of only 1 kw. of energy, or about 40 such lamps to the horse-power. These results may possibly be much exceeded, for the research laboratory it not yet through its work.

In recent years, as with incandescent lighting, electric arc lighting has been completely revolutionised. For a long time the arc between carbon electrodes was relied upon solely. It was at first open to the air—the so-called "open arc." Later the enclosed arc or carbon arc, with a restricted supply of air, served to minimise the consumption of the electrodes, but at a sacrifice of efficiency of light production. Recently we have seen the introduction of the various forms of flame arcs, luminous arcs, and the mercury arc lamp with its greenish light. By loading the electrodes of an arc with mineral or metallic compounds the main source of light is the flame between the electrodes, and not, as in the carbon arcs, the hot ends of the carbons themselves.

Many of the streets and open spaces in our large cities are now lighted by magnetite arcs, so named because the electrode which furnishes material to the arc is composed principally of magnetic oxide of iron, mixed with other substances destined to improve the colour, steadiness, or efficiency. Development in this field is still going on actively. The characteristic arc light dynamos of former years are now seldom built. Mercury rectifiers instead convert into direct current the alternating currents from constant-current transformers, which, in turn, receive energy from the general supply mains extending from the great electric stations, which mains supply energy for incandescent lights or motors, and for other uses.

The tendency is now to generate in the station but one type of current, and supply all needs therefrom. A 3-phase, alternating-current supply, working through rectifiers, transformers, converters of various types, gives electrical energy in any form and at any voltage required. Thus the Fisk Street Station in Chicago has a capacity of 160,000 h.p., and in it the 3-phase, steam turbine dynamo units range up to 27,000 h.p. each, all varieties and conditions of load partaking of this enormous output.

While in the early days of electric stations lighting was the only load, it was foreseen that the distribution of power would eventually become of great importance. In recent years the application of electric motors has made enormous strides. They are fast becoming a universal adjunct to moving machines, replacing all small stationary steam engines and gas engines. Electric motors have already become a component part of machine tools, and of many other machines formerly driven by belts from line shafting.

Perhaps, however, no better example of recent progress can be found than a modern high-tension transmission system, for it may combine within itself all those features which have made electricity such an important factor of our later civilisation. In such a transmission system there may be several generating stations far apart tied into the lines or network for conveying the electrical energy. In these stations water power may be used to drive the dynamos, or steam, or both, or even internal-combustion engines may exist. As generated, the electrical energy is too low in voltage for long-distance transmission. It may be, say, at only 2,000 volts, while the transmission requires 100,000. In fact, a plant has recently been put into operation in which the line voltage is as high as 140,000. To obtain this increase of pressure the station current is "stepped up" by giant induction coils or transformers receiving the 2,000 volt current in their primary coils, and delivering to the line 100,000 volts from their secondary winding.

Accurate instruments measure the output in amperes, volts, watts, and other factors. In the large stations the manipulation is often by a system of "remote control," whereby, by means of electric relay apparatus, outputs of many thousands of horse-power are controlled by a single person operating push-buttons or small master switches. Here, also, signals and instruments exist for showing him the operating conditions of the plant at any time. Telephones connect the various stations, and parts thereof, over hundreds of miles. Automatic lightning arresters, fuses, and circuit-breakers are on guard in case of accident.

Sets of line wires of copper or aluminium, three wires in each set, lead off into the far distance from these great stations, and are supported on high-tension insulators, which are sustained on poles, or upon tall towers of latticed steel. These lines are very much alive. They are dangerous to approach; for the kind of electricity they carry is second cousin to the lightning, for it can jump spaces of many inches. If we follow such a line we may find that it leads to a substation near a town, or to a group of factories, or to a substation power-house operating a railway or a mine. Here it is "stepped down" by reversing the process which gave the energy its high pressure. Step-down transformers reduce its voltage to a more manageable amount; perhaps to again about 2,000 volts. These transformations have caused but small loss, for the efficiency of the large transformers is but little less than 100 per cent. We find again, in the step-down station, the measuring instruments, automatic apparatus, and appliances for control. And now lines lead off in various directions carrying the 2,000 volt current, some of which is finally again transformed down, perhaps, to 100 or 200 volts, for low-tension supply on the consumer's premises, where his electric meter registers the amount of energy used by his lights, his motors, and the like.

Part of the energy may, through rectifiers, supply the current for the arc lights on the streets or in the stores. Vacuum-tube lights even may be operated. Electricity has given us sufficient variety in our means for producing light. Another part of the energy may be changed, by machines called rotary converters, and adapted to the operation of railway car motors, which need a direct current of about 600 volts.

Still another fraction may work apparatus employed in charging large storage batteries, or may be further divided and rectified for the batteries of automobiles. Energy may be taken from the system for electric stoves or cooking apparatus, or for warming. It may be also consumed in heating metal, as in electric welding, or in electric purposes. It may produce ice in refrigerating machines driven by electric motors. The applications of electric motors are already innumerable. The time will come when cooling in summer will not depend on ice delivered at our doorsteps or in our refrigerators. We may turn a switch, setting in motion a small refrigerating apparatus which transfers heat from water to be cooled or frozen to other water to be warmed. A modicum of the electric output may go to the uses of the physician in such indispensables as Rontgen-ray tubes. The dentist also calls for his supply.

In recent years electricity has added to our resources many remarkable and valuable products. Among those are carbide of calcium and from it acetylene gas. The electric

furnace gives us such ideal grinding materials as carborundum and alundum. By way of contrast to these, it furnishes artificial graphite for lubrication. It furnishes supplies of such elements as silicon and boron, until recently practically unknown even in the laboratories.

Aluminium, magnesium, sodium, calcium are made commercial products by electrolytic methods of production. Through cheap aluminium we have thermit for welding. We also obtain by it pure metals, such as manganese, for forming alloys. Lastly, in late years large electric furnaces enable us to secure high temperature for refining great baths of steel, or producing special high grades from crude material. Electrochemical baths refine our copper and yield such products as chlorine, caustic soda, and bleaching powder, as well as the chlorates. Special electric furnaces give us phosphorus for matches, and others carbon bisulphide. Within a few years past water-power has been employed, as in Norway, in the commercial production of nitrates, by combining the nitrogen and the oxygen gases of the air in huge, specially-formed electric arcs. These nitrates add to our agricultural resources, on which the food supply and, as a consequence, the population of the world depend.

It would be out of place here to recount the numerous improvements which our electrical machines are constantly undergoing. There are many minor advances, improvements in design, in disposition and character of materials, in manufacturing methods, and the thousands of things that contribute to an art so varied and extensive in its field.

Very recently I came across by accident an article on the "Future of Electricity" which I had written for a magazine now defunct. It was published in 1892—just twenty years ago. The forecast therein given has not only in the main proven true, but in not a few instances has been many times exceeded. Wireless telegraphy, then predicted as a possibility between ship and shore for moderate distances, in spite of storm and fog, has crossed the Atlantic. Telephony, alluded to as feasible over hundreds of miles, has thousands to its credit. Long-distance transmission of electric energy has very greatly exceeded our most sanguine anticipations of twenty years ago. Our dynamos are of far greater capacity than any of us could have imagined possible. In all directions our expectations have been far exceeded, and unexpected new discoveries have opened up a range of newer applications. We must leave the future to tell its own story, lest we repeat the same underestimation.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

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Metallic packing for steam engines. Brook. 10178.
Steam generating plants. Sanderson. 15598.
Taps or valves. Whyte. 16220.
Pumps for internal-combustion engines. Mather & Platt, Ltd., and Chorlton. 17594.
Motor driving gear. Redrup. 17623.
Apparatus for heating and filtering boiler feed water. Morison. 17638.
Blast pipes for locomotive engines. Kay. 17641.
Device for cleaning boiler tubes. Nasmith. 17642.
Machines for machining the surfaces of screw propellers. Joushkievich. 17691.
Condensing means for terminal exhaust engines. Neukommn. 17754.
Reversible rotary engine. Lambert & Resch. 17787.
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Rotary explosion engines. Conill. 17901.
Burners for drying moulds. Deutsch-Luxemburgische Bergwerksund Hutten-Akt.-Ges. 18013.
Burner for drying moulds. Deutsch-Luxemburgische Bergwerksund Hutten-Akt.-Ges. and Keibel. 18134.
Tubular evaporating and concentrating apparatus. Rossi. 18163.
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Furnace fire bridges. Condron. 18304.
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Ignition systems for internal-combustion engines. Flint. 18699.
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Locomotive furnaces for economising fuel and preventing sparks. Hill. 21061.
Testing machines. Joshua Buckton & Co., and James. 21379.
Conveyers. Heenan & Froude, Ltd., and Leask. 23126.
Steam superheaters for locomotive boilers. Robinson. 24172.
Vacuum brake apparatus for railway vehicles. Luard. 24450.
Governing mechanism for elastic fluid turbines. Warwick Machinery Company (1908). 24678.
Valves for gas distribution. Robert Dempster & Sons, Ltd., and Horsfall. 24720.
Portable lifting jack. Little. 26280.
Apparatus for simultaneously conveying and grading materials. Fairweather. 26678.
Shaft bearings. Evans. 27077.
Steam traps and regulators. Lord & Barlow. 27143.
Apparatus for pumping elastic fluids. Humphrey & Rusdell. 28187.
Die-casting machine. Whiteman. 29112.
Tool heads. Tye. 29123.

1912.

Devices for operating tramway points or switches from the vehicle. Karnauke. 92.
Gas turbines. Wedekind. 4350.
Steam generator furnaces. Anderson, Meikle, & Fulton. 4446.
Water-tube boilers. Yarrow. 5114.
Combined vice and hand file shaping machine or attachment. Cranston. 5882.
Boxes for moulding metals. Morrison & Aspinall. 6341.
Arrangement of jockey pulleys for rope drives. Geburtig. 8192.
Furnace doors. Imray. 8882.
Water cooled furnace door frames. Imray. 8884.
Taps or valves for water and steam. Shanks. 10248.
Measuring machines. Williams. 10445.
Tube cleaners. Struthers. 10790.
Process for the electro-deposition of zinc. Ballegeer. 11271.
Friction clutch. Robertson. 11308.
Nut locks. Deschamps & Bablon. 11704.
Apparatus for signalling on trains and for stopping trains. Gottschalk. 11762.
Fuel-injecting apparatus for internal combustion engines. Fried. Krupp Akt. Ges. Germaniawerft. 13412.

ELECTRICAL, 1911.

Controller and regulating resistance for electric motors. French. 6997.
Means for regulating electric lamp circuits. Leitner. 17791.
Electrical heating apparatus. Welch, and Harvey, Frost, & Co. 17810.
Magneto electric apparatus. Douglas. 17932.
Wireless telephony. Matthews. 18284.
Dynamos. Price. 18526.
Automatic starters for electric motors. Field. 18611.
Electrical appliance for transmitting messages with provision for taking a record of each message and notifying the record to the sender of the message. Davies & Mason. 19210.
Ignition plugs. Longford, Longford, & Clark. 20207.
Arc lamps. Ridings. 21735.
Controllers for electric motors. Bennitt. 21800.
Vapour electric apparatus. Hewitt. 21904.
Distribution of electrical energy. Hunter & Shand. 22624.
Electrolytic apparatus. Knowles. 22759.
Apparatus for actuating conduit covers and collector ploughs of electric railways. Samaia. 23495.
Electric lighting and heating of railway vehicles. Pintschs Patent Lighting Company, and Vidal. 24552.
Automatic telephone systems. Betulander. 25216.
Process for the electrical welding of the seams of tubes. Ges. fur Elektrotechnische Industrie. 26440.

1912.

Incandescent electric lamps. Singley. 3348.
Control of variable-speed dynamos. Electric and Ordnance Accessories Company, Etchells & Price. 6269.
Electric incandescent lamps. Hyde. 6487.
Frequency indicator for alternating currents. Thompson. 7658.
Electric resistance devices. Cooper. 9861.
Submarine cables artifically loaded with self induction. Siemens and Halske Akt.-Ges. 10053.
Driving arrangements of ignition magnetos. Hill. 12193.
Arc lamps. Harlé & Cie. 13358.

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The Invention of the Steam Engine.

THIS year is the two-hundredth anniversary of the first practical piston steam engine, which was built at Dudley Castle, near Wolverhampton, by Thomas Newcomen, in 1712. The steam engine, like other great works, was not the result of a single brilliant idea, nor even the work of any one great genius and inventor. Before Newcomen, others had made efforts to utilise the energy of steam, and when Newcomen died there was still much to be done. Whilst recognising the work of others, it does, however, appear that the first Newcomen engine was the parent of all reciprocating steam engines. It is, therefore, fitting, on the two-hundredth anniversary of an event of such importance, that we should review the early history of the steam engine and do honour to the Englishman who, more than anyone else, gave it to the world. In these days of high pressures we are apt to forget that early steam engines were low-pressure engines. Indeed, it would almost be more correct to call them vacuum engines than steam engines, for the engines worked by reason of a vacuum being produced in the cylinder. A vacuum, of course, is only useful because it gives a pressure below atmospheric, and hence, as an alternative, the early engines might very well be called, as, indeed, they often were, atmospheric engines. The name is not of first importance, but it is well to bear in mind that the early engines were designed as vacuum engines, and their earliest beginnings are closely wrapped up in experiments on the weight and pressure of air and means for producing a vacuum. Galileo, in the early part of the seventeenth century, is believed to have held the view that air had weight, but the first demonstration of this fact is accredited to his pupil, Torricelli, who, in 1643, made two barometers, of water and mercury respectively. The fact that the heights of these two apparently unsupported columns of fluid were inversely as their specific gravities showed that the air exerted a definite pressure. Twenty years later the Royal Society, then just founded, devoted some of its meetings to the weighing of air, to the

great amusement of King Charles II. Following upon Torricelli's experiment philosophers began to seek means of producing a vacuum at will. One of the earliest and most successful was Otto von Guericke, of Magdeburg, who invented an air pump in 1650, and in 1654 raised large weights by means of a rope attached to a piston working in a cylinder, a partial vacuum being produced in the cylinder by connecting it with a vacuous vessel. Others, including Boyle and Hook in this country, Huyghens in Holland, and Papin, a Frenchman, experimented with air pumps, and more or less directly helped forward the birth of the steam engine. Another means for producing a vacuum, which was frequently tried by the inventors of this time, was gunpowder. Huyghens in particular constructed a piston and cylinder which raised a heavy weight by the creation of a vacuum under the piston by the explosion of gunpowder.

Of the philosophers, however, Dr. Papin was the most fertile in devising engines to work by the force of a vacuum, which he produced by means of an air pump, by the explosion of gunpowder, and by the condensation of steam. Incidentally, it is interesting to note that Papin's air pump is depicted in several drawings as being worked by a rotating shaft with a cranked axle and connecting rods, but it does not appear that he used the reverse arrangement in which the power is applied to the crank shaft through connecting rods and cranks. Papin was one of those unfortunate geniuses who come very near to doing great things, but always fall just short of the great prize. He appears to have first suggested the use of steam to produce a vacuum for these mechanical engines.

Thomas Savery, a native of Devonshire, is often spoken of as the inventor of the steam engine, but the description is hardly correct. He certainly was a pioneer in this field, and did much useful work. On July 25th, 1698, he took out a patent for what became known as a fire engine, but which was really a steam pump of the pulsometer class. Steam was supplied by a high-pressure boiler to a pump chamber which in turn was connected by pipes with non-return valves to the water suction and delivery. The steam filled the chamber and delivery pipe. The steam cock being then closed, cold water was poured over the outside of the pump chamber. This condensed the steam producing a vacuum, which sucked up the water into the chamber. The steam cock was then again opened—in all cases by hand—and the steam, pressing on the surface of the water, forced the water up through the delivery valve. The first Savery engine seems to have been set to work about 1702, and great things were hoped from it for mine pumping. For this purpose it proved a comparative failure, although it succeeded well in a few instances when pumping water for gentlemen's houses. The explanation was that coal mines were usually too deep for one pump to raise the water. Boiler making was not a highly-developed art in those days, and the limit to which water could be pumped in a single lift was the suction (say, 20 or 25ft.), plus a head rather less than the steam pressure. This total lift did not exceed from 60 to 80ft. It is recorded that a Savery engine, erected at Wednesbury, near Wolverhampton, was abandoned because the force of the steam tore it all to pieces. It is interesting to note that a Savery engine in those days cost about £50 to build, apart from profit, although, of course, the scale of values in those days was not the same as at present, £50 being a much more considerable sum than it is to-day.

After Savery, Newcomen. Thomas Newcomen, the man to whom, more than to anyone else, belongs the title of inventor of the steam engine, was brought up at Dartmouth. Newcomen was originally an ironmonger, and in some of his steam engine work had the assistance of John Cawley, a glazier; although Cawley does not appear to have played any leading part. Newcomen was a friend of Savery, and was also acquainted, through Dr. Hook of the Royal Society, with the experiments of Papin. No doubt he pondered over the experiments of these two pioneers, but his own first public attempt was so great an advance on anything previously accomplished that, in so far as the title can be given to one man, Newcomen may be fairly called the inventor of the steam engine. It was not merely that his engine showed evidences of remarkable genius and practical ability, but even more, that the engine was the father of all the reciprocating steam engines which have been built. Savery's so-called fire engine bore no resemblance to the steam engine as it has been known for two hundred years. Papin's contrivances bore some resemblance, but never got beyond the toy stage. Newcomen erected his first engine at Dudley Castle, near Wolverhampton, in 1712. Drawings of the engine have been preserved and give a clear idea of it. The boiler was circular in plan with the steam cylinder placed vertically a short distance above it. The piston of the cylinder was connected by a chain to one end of a rocking beam, to the other end of which were hung the pump rods; for, like all the early engines, this one was arranged for pumping. A small pump, also driven by the main beam, supplied the boiler and condensation water. The valves were operated automatically, partly by a buoy floating in a pipe open at one end to the atmosphere and dipping at the other below the boilerwater level, and partly by a tappet motion derived from the feed pump rod. Thus this first Newcomen engine embodied the piston and cylinder, the automatic valve gear and internal condensation; none of which were to be found on the Savery fire engine. The automatic gear is particularly to be noted, because there still lingers a popular belief that the automatic gear was the invention of a boy named Potter, who devised it so that he might continue his play instead of having to turn the various cocks by hand. The Dudley Castle engine made 12 strokes a minute and raised 10 gallons per stroke from a depth of 50 yards. The Newcomen engine was not long in finding favour. It was a practical working engine, and, moreover, was not limited in the depth from which it could pump. Thus it soon found its way into colliery districts, and the more so because the collieries were much troubled by water and could afford coal.

Following upon Newcomen, several engineers helped to establish the steam engine. Of these, Smeaton deserves mention, but it was James Watt who effected the greatest advance. It was Watt who first studied the science of the steam engine, and enunciated the first principles of applied thermodynamics. Reasoning on the properties of steam, he concluded that the cylinder should always be kept hot, and that, therefore, the cylinder should not be used to condense the steam. This led him to devise the separate condenser. He also made the engine double-acting and applied it to obtain a rotary motion by means of sun and planet wheels, which, however, were simply a device for overcoming the patent right to the crank. Another invention which has left its mark was the pendulum governor. Watt himself also favoured the use of high-pressure steam expansively, but for the most part his engines were vacuum machines. Following Watt were several notable steam engineers. Among the more important were Richard Trevithick, who experimented so successfully and boldly with locomotives using high-pressure steam, and William Symington, who built the first steamboat, the "Charlotte Dundas," in 1801.

In 1812 the "Comet" was built for Mr. William Bell, a Clyde hotel proprietor, the centenary of which has just been celebrated by a display of shipping on the Clyde. Fairness demands, however, that the prior claims of Robert Fulton, an American, to be the designer of the first commercial steamboat, should be recognised. His boat, the "Clermont," commenced running on the Hudson river between Albany and New York, in 1807. This boat was in every way far superior to either the "Comet" or the "Charlotte Dundas." Such, in brief, is the story of the early invention of the steam engine. Of the changes which the Newcomen engine of 1712 set in motion, it is impossible to convey an adequate impression. The world to-day is as different as possible in all the ways that man can make it from the world of 200 years ago, and this revolution we owe more to the steam engine than to anything else. He would be a dull person, indeed, who could think of these changes without an inward stirring and mingled feeling of pride of the past and determination for the future.

RAIL PLATEWAYS.

In the last issue of the journal of the Society of Engineers Mr. G. Noble Fell, A.M.Inst.C.E., contributes an interesting article on rail plateways, of which the following is an abstract:

Some years ago, the late Mr. Alfred Holt, of Liverpool, and a number of gentlemen interested in the trade of Lancashire and Yorkshire, grasped the idea that if the raw material could be conveyed from the ship direct to the mill, and the manufactured article from the mill to the market, a large saving might be effected in the cost of production. These gentlemen applied themselves to the task of solving this problem, and devised a plan whereby road wagons and lorries could be run over a plateway worked by mechanical means. Unfortunately their efforts were not successful, owing to the heavy expenditure involved in the method devised, estimated at no less than £48,000 per mile of plateway. One can readily understand that at this figure no great saving could be effected over carriage by rail.

A plateway, pure and simple, that is, a track laid along the public highway to facilitate the passage of ordinary vehicles, is a failure in this respect, and does not meet the requirements of the case. What is necessary is the application on such a track of the best means of propulsion (whether steam, petrol, or electric) to work the traffic economically and expeditiously. To do this the track must first of all be removed from the public road, and placed on its own acquired ground. Next must be provided a suitable permanent way, that will carry a locomotive, a railway wagon, and a road vehicle. This is quite practicable, as will be seen by reference to Fig. 1, which shows a special form of plateway rail, A being the space provided for the flanged wheels of the railway stock, and B the space on the same rail allotted to the wheels of the road vehicles. The gauge adopted is 4ft. 8½in., so as to allow of the circulation of ordinary railway wagons over the plateway, and it is proposed to carry road vehicles of a width not exceeding 5ft. 6in. over the wheel tracks (that is, the measurement from outside to outside of the wheels at ground level), the intention, however, being to construct suitable road wagons for working on the plateway and so to avoid the expense of altering existing wagons to suit railway traction, in such matters as couplings, draw-bars, brakes, &c. The specially-designed rails are laid on a longitudinal foundation formed of concrete, or timber and concrete combined, to which they are securely fastened by means of spikes and bolts. This form of support, or road bed, does away with the ordinary cross sleepers and ballast, and constitutes a solid track, giving a continuous bearing, and enabling a lighter form of rail to be used.

A further departure from the ordinary methods of railway construction is the adoption of a third or centre rail, which is used to assist traction on steep inclines. The cross-tie above-mentioned is so constructed as to form a chair, raised slightly above the carrying rails. The tie is secured to longitudinal beams, and supports the centre rail, upon which run horizontal wheels. These wheels on the locomotive are worked by a separate pair of cylinders, and are made to grip the rail by means of elliptic springs, thus giving the engine the additional adhesion necessary for overcoming steep gradients. Horizontal wheels with flanges running under the head of the centre rail may also be attached to the wagons and carriages, to guide them round sharp curves, and to make it impossible for a vehicle to leave the track when descending a hill. Gradients up to 1 in 10 have been successfully worked for many years by this system, and there is no reason why steeper gradients than this should not be overcome, especially where electric traction is adopted. The centre rail is used also for brake purposes, the brake acting directly on the two faces of the rail, giving absolute safety on steep inclines. With the above system the author has travelled down gradients of 1 in 10, at a speed of 40 miles an hour, with perfect safety. Naturally, on level ground the central rail is not required, and the engine is worked by the two outside cylinders and carrying wheels alone, and when an incline is reached the driver, by putting the horizontal wheels into motion, can take the train up the hill as easily as it travels on the level. No change of engine, nor even change of gear, is necessary. These engines are working on the Rimutaka incline in New Zealand, where the system was adopted by separating Wellington and Masterton. The saving as compared with a railway of ordinary construction, was estimated at over £100,000.

A special form of level crossing has been devised for roads, where the centre rail is laid, and means are provided whereby the road vehicles can be removed from the track when required to resume their journey by road, or vice versâ. This is done by tapering the longitudinal guard rails in the

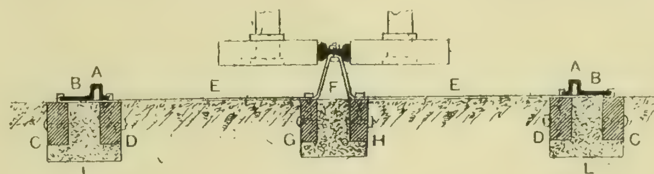


FIG. 1.

direction of the line, so as to form an incline, up which the wheels of the vehicles can be drawn to the level of the roadway. The same means will apply to stations, and to other points where it is desired to rail or derail vehicles.

It may here be noted that plateways are not intended to and cannot compete with existing railways; they are to become feeders, and to constitute a means of bringing traffic to them, and distributing traffic for them, in a more expeditious and economical manner than has hitherto been possible. They will form an intermediate means of transport.

In order to keep the cost of construction as low as possible, and so to bring these plateways within the means of every district not possessing railway accommodation, the axle loads will be limited to 5 tons, that is to say, a 10-wheeled locomotive not exceeding 25 tons in weight will be sufficiently powerful to deal with the class of traffic to be carried, and will be capable of working on the gradients above-mentioned. As the gauge of 4ft. 8½in. will be adopted, the ordinary light stock of the existing railways will be able to run over the plateways, and transhipment of freight will thus be avoided. There is no reason why road motors should not utilise the plateway.

Several types of plateway have been studied, that shown in Fig. 1 being designed to carry locomotives up to 25 tons weight, and ordinary railway trucks weighing 10 tons loaded, or bogie trucks weighing 6 tons each and carrying a load of 14 tons. This type is laid with two specially rolled-steel rails, weighing 50lbs. per lineal yard, carried on the longitudinal timbers C D, to which they are spiked in the usual manner. These beams are in their turn carried on, and bolted to, concrete foundations, the upper surfaces of which correspond with the ground level. The two rails are braced together by the steel tie-bar E, whereby the gauge of the line is kept in proper adjustment. On steep inclines this tie-bar also serves the purpose of supporting the centre rail, as it forms a chair

(shown at F), to which the rail is bolted and fish-plated in the usual manner. This chair is carried on, and secured to, two longitudinal beams G H laid in concrete, and the whole permanent way is thus framed together in a very solid manner. This form of permanent way, including the centre rail and foundations, is estimated to cost £1,300 per mile, calculating labour and materials at average present-day prices. A plateway constructed on this system over a hilly country and capable of hauling traffic up inclines of 1 in 10, may be built for £5,000 a mile. The cost of an ordinary railway, over similar ground, would be from £10,000 to £15,000 a mile, besides the cost of the extra length of line that would be required for reaching the same altitude with a 1 in 40 grade.

Let us see what will be the carrying capacity of such a plateway. Take a line 20 miles in length, divided into three sections, and suppose that there is a length of 5 miles at each end with gradients of 1 in 10, and that the intervening portion is undulating country with normal grades, which would represent a line rising from sea-level to a plateau at an elevation of 2,640ft., and falling again to sea-level, that is, a line connecting two valleys separated by a broad range of hills. At speeds of 15 m.h. on the level, and only 8 m.h. up, and 15 m.h. down the inclines, the journey can be made in 1 hour 35 mins., and by running the engine a double trip on the first incline, so as to give a full load for the rest of the journey, the round trip can be made in 5 hours, allowing ample time for shunting, coaling, &c. A centre-rail engine of 25 tons weight will take behind it a gross load of 49 tons up a grade of 1 in 10, or a net paying load of 28 tons; the net double load will therefore be 56 tons, and one engine could make three round trips in 15 hours, carrying a total net load of 336 tons. With four engines running, therefore, 1,344 tons may be carried in a day, or a total paying load of 403,200 tons in 300 working days.

Instead of a double-headed rail, an H or channel bar may be used as a centre rail where the traffic is light. The carrying rails may also be formed of T bars. With this form, however, it will be necessary to provide a flange for keeping wheels of the road vehicles on the track where the centre rail is not laid. The cost per mile of this type of permanent way, including the centre rail, is £920, and the estimated cost of one mile of plateway is £3,750 over a hilly country and £2,500 a mile on fairly level ground.

An example of a light railway of this description, where light timber viaducts were substituted for heavy banks and cuttings, is the Torrington and Marland Railway, in North Devon, mentioned in Mr. Vernon-Harcourt's work on "Railway Construction." It is eight miles in length, the gauge being 3ft., and although there are many viaducts of from 20ft. to 25ft. in height, and a bridge of three 45ft. spans, and 40ft. high, over the River Torridge, the total cost of construction was only £20,000, or at the rate of £2,500 a mile. It was opened in 1880, and is still carrying a heavy mineral traffic. It is intended to utilise similar light viaducts in timber or steel for the system of plateways now proposed, in order to secure economy and rapidity of construction, and this method, combined with plateways and the centre rail system of traction, will be an entirely new departure in railway building. The cost of working the Torrington and Marland Light Railway, for the year ending December 31st, 1911, not including the cost of management, was 1½d. per ton-mile.

THE PRODUCTION OF BLACK NICKEL.

In the current issue of "The Brass World," the following particulars are given of a black-nickel plating solution which our contemporary states the test of time has proved to be quite satisfactory and permanent.

The formula for the black-nickel solution is as follows:—

Water	1 gallon.
Double nickel salts	8 oz.
Ammonium sulphocyanate	2 oz.
Zinc sulphate	1 oz.

The double nickel salts are the regular nickel salts employed in making up a nickel plating solution, and are the double sulphate of nickel and ammonia. Either ammonium sulphocyanate or potassium sulphocyanate may be used, but the ammonium sulphocyanate is slightly cheaper. Sulphate of zinc is the well-known commercial grade. It is unnecessary to use chemically pure materials; any well-known standard commercial brands answer the purpose.

To make the solution, dissolve the double nickel salts in the right amount of clean water, either cold or hot, and then add the ammonium sulphocyanate and sulphate of zinc. Mix well and allow to cool. It is unnecessary to filter it. The solution is run cold, but in winter, when the temperature is excessively low, it should be warmed to about 70° Fah.

The anodes used in the black-nickel solution are the regular anodes employed for nickel plating, but better results are obtained if old instead of new ones are employed. Old anodes give up their nickel more readily than new ones, and it is for this reason that they are preferred. To be sure, new anodes can be employed, but the solution will not work regularly with them for as long and will require attention sooner.

One thing should be borne in mind and that is to have plenty of anodes. It is false economy to use too few, for then the solution will become acid sooner and work irregularly. When plenty of anodes are used, the solution will work in a normal manner for the maximum time, and the solution will be fed properly. There cannot be too many anodes used.

As the black nickel does not "throw" as well as white nickel, the anodes are preferably placed on both sides of the article, or around it, as the case may be, so that the current will pass evenly. In this manner it is possible to cover any surface evenly and uniformly. The anodes should be cleaned from time to time.

The regulation of the current used in depositing black nickel is the most important feature of the operation, and upon it depends the success of the process. Not over 1 volt should be used. A greater quantity will cause the deposit to become streaked, and if an excessive quantity is used, it will be grey or white. This current regulation is very important, and it is impossible to obtain satisfactory results unless the current is cut down to the amount previously mentioned. It is in the matter of current regulation that platers usually err, and the principal fault is to use too strong current. If a good black nickel is desired, then the current must be maintained at 1 volt and no more. Bear this in mind.

When the solution has been properly made and the current density has been adjusted to the right amount, the first flash of black nickel deposit will be irridescent, but will cover the whole surface of the article being plated. This takes place within a few seconds but gradually. When the irridescent colour forms it indicates that the solution is in proper working order. A black colour should not form at once, but should be obtained by first producing the irridescent deposit. After the irridescent deposit has formed, and the current has passed for a short time longer, it disappears, and a blue colour makes its appearance. This, however, gradually changes to the black, the real colour of the black nickel.

The length of time taken for the electrode-position of the black nickel may be from 10 to 20 minutes. It should be borne in mind that the deposit is not a pure metal, but a sulphide of nickel, and is somewhat brittle. For this reason it is essential that the deposit should be light. It is a common error to produce too heavy a deposit. It is apt to flake off and nothing is gained by it. When the article has a uniform black colour on the surface, the deposition can be stopped. To carry on the deposition for a long time produces a hard and thick deposit that is quite apt to flake off. A thin deposit, when the colour has been obtained, is sufficient.

The base metal, upon which the black nickel is to be deposited, may be of any metal that can be plated with white nickel. It is needless to say that the surface should be clean and free from tarnish. Very careful preparation, therefore, is needed, for the black-nickel solution has no grease-removing properties. Some platers claim that better results are obtained by first giving the article a white deposit, and then deposit the black nickel on it. Whether this is true is doubtful, and if it is used, then the deposit of white nickel should not be buffed, as it will then be difficult to clean. Only a flash deposit should be used at any event.

If the surface of the base metal is buffed, then the black nickel deposit will be polished. Dead surfaces likewise produce a dead black nickel. In this connection it may be stated that the polished or buffed surface upon which the black nickel is deposited should be used whenever possible, as the black nickel deposit is then dead black. Upon dead surfaces it has

a grey shade, or is slightly off colour. The blackest shade is obtained on polished surfaces.

The solution should be maintained in a strictly neutral condition. If it becomes acid, then the deposit is either streaked or grey. If alkaline, the deposit is brittle and will easily flake off. When freshly made, the solution will stand between 6° and 7° Beaumé, and water should never be added to it. The best results are always obtained when the solution is strong. Water will make it plate grey.

As the solution is used, it will gradually become acid, for the reason that the nickel is not obtained from the anodes in sufficient amount to compensate for that deposited. When plenty of anodes are used, however, this will take place only after some time. When this is the case the deposit will become streaked. To bring back to its original condition, ammomia should be added to it in small quantities at a time, the solution thoroughly stirred, and then tested with litmus paper. The right condition is obtained when red litmus paper does not turn blue, or blue litmus paper red. Such a condition is one of neutrality. The bath has the appearance of any nickel solution, that is, light green, and should under no consideration be blue. This indicates too much ammonia has been added.

The colour of the black nickel, when it first comes from the solution, leaves nothing to be desired. Upon standing, however, it is apt to have a brown shade. This brown shade frequently is seen when the article is removed from the bath. A grey shade is likewise often present. While lacquering will remove the brown shade, it will not completely mask the grey colour. For this reason it is frequently advisable to use a dip to remove the brown or the grey shade. This dip is composed of the following:—

Water	1 gallon.
Perchloride of iron	12 oz.
Muriatic acid	1 oz.

The articles, after they have come from the black nickel solution, are rinsed in cold water and then immersed for a few seconds in the preceding dip. This will remove the brown or grey shade. They are then rinsed in cold water, then in hot water, dried, and lacquered.

This dip is slightly acid and has the property of removing the brown or grey shade on the black nickel deposit produced by the presence of sulphide of zinc.

It is always advisable to lacquer the black nickel deposit if possible, as it not only serves to protect the surface, but prevents discoloration. All black nickel deposit will show a slight discoloration upon standing in the air, but which may be removed by buffing or wiping. The lacquer, however, will prevent this difficulty.

The following notes will serve to indicate the source of the difficulty found in plating black nickel:—

1. The deposit has spear-shaped markings on it and is partly white.

Remedy.—Use a weaker current.

2. The deposit flakes off after the article has stood for some time.

Remedy.—The deposit is too heavy, and the electrodeposition has consumed too long a time.

3. The deposit is white.

Remedy.—The current is too strong or the solution has become acid. Use a weaker current or neutralise with ammonia if acid.

4. The deposit is still brown or grey after coming from the dip.

Remedy.—The dip is old or the article has not remained in it sufficiently long. Make a new dip or leave the article in longer.

5. Although the voltage is right, the deposit is streaked.

Remedy.—The solution has become acid and requires neutralising with ammonia.

6. The edges of the deposit are removed by the dip.

Remedy.—The dip is too strong or the deposit is not sufficiently heavy. Use the dip cold. Do not leave in the dip for more than a few seconds.

If care is taken in maintaining the right voltage and keeping the solution neutral, no difficulty will be experienced in obtaining a good black nickel deposit.

NEW DEVELOPMENTS IN STEAM TURBINE ENGINEERING.*

BY EDWIN D. DREYFUS.

(*Concluded from page 255*).

Marine Application.—Turbines were first introduced into marine vessels in 1894 when the "Turbinia" was so equipped. The trials of this ship pointed definitely to the practicability of the turbine for this service, and the results have been so favourable that there have been installed, to date, an aggregate of over 6,000,000 h.p. of turbines in marine service, embracing all classes of war vessels, merchant marine, and pleasure yachts.

It should be noted that in the impressive capacity represented by marine installations, all turbines have been direct coupled to the propeller shafts, with possibly one or two exceptions. Notwithstanding the remarkable recognition already accorded the marine turbine, it must be acknowledged that the turbine has in these cases been installed under a disadvantage. Again, there is a compromise of speeds between that of the turbine and propeller, such that their designs and efficiencies are prejudiced when direct

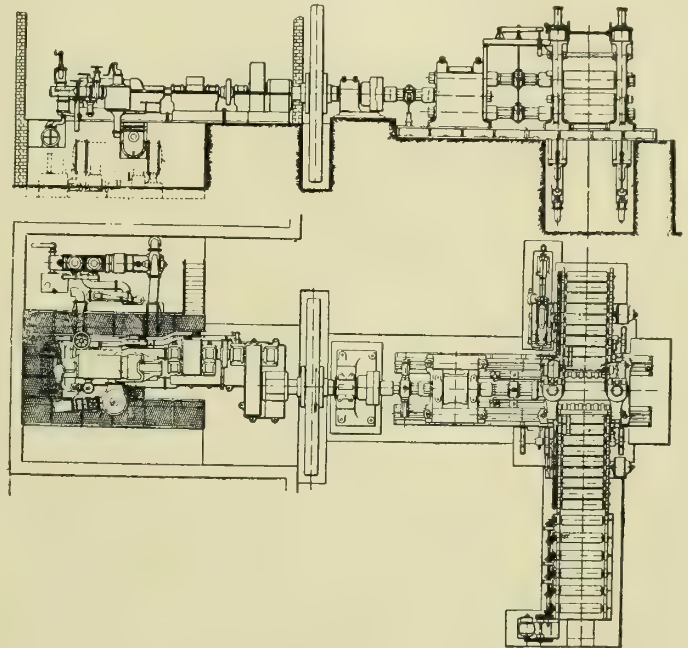


Fig. 16.—Turbine Applied to a Rolling Mill.

coupled. It is not surprising, therefore, that the experience of the United States Navy Department has not come up to expectation. Records show that propellers for engine and turbine-driven vessels have developed coefficients of 65 per cent. and 53·8 per cent. respectively, evidently handicapping the turbine where direct drive is employed, and little, if any, has been gained in weight, space, and efficiency owing to the bulk and poor steam distribution required by the low speeds. Space will not allow of a more critical discussion of the subject at this time, but the reasons before cited show that we may with surety look forward to the marine turbine being given a new standing and fresh impetus through the interpolation of the reduction gear.

The effect of the increased efficiency of both turbine and propeller in a marine installation has even a more far-reaching effect, as a large reduction in coal bunker capacity is also brought about, and moreover the boiler horse-power required is reduced approximately one-third. The saving of one-third of the space occupied by these boilers will be seen to be a very large item. As each of these ships carry 192 firemen and 123 trimmers, the reduction of the number of boilers to be fired would effect a material reduction in the expense for this part of the crew.

There is another consideration which deserves mention, viz., if the increased space made available by the reduction in boiler and engine room and bunkers could not be profitably used, the general proportions of the vessel might be decreased, which would immediately have an accumulative

* Paper presented before the Western Society of Engineers, March 4th, 1912.

effect and again reduce the amount of power required for propulsion.

The requirements for war ships are very different from those of fast passenger ships which run normally at full speed, as war ships run at full speed only in case of emergency. When cruising, they use less than one-fourth of full power. As the efficiency of the existing marine turbine rapidly falls off at reduced (rotative) speeds, the steam consumption per horse-power hour becomes serious when the ship is running

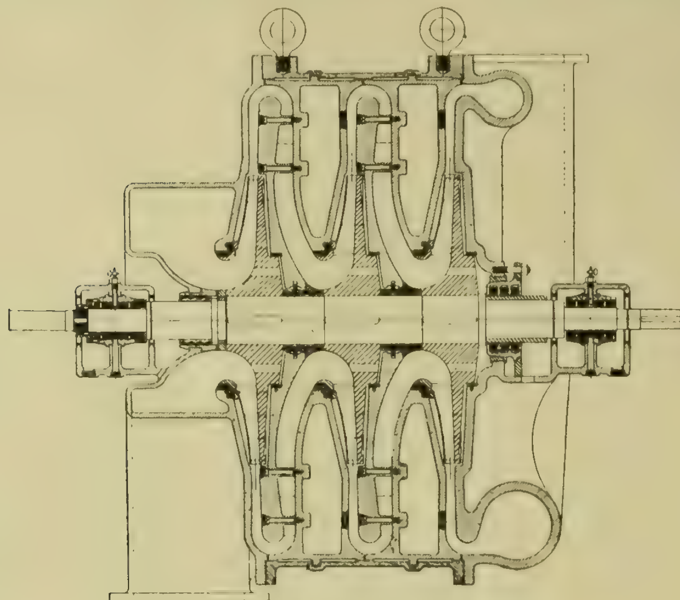


FIG. 17.—TURBINE APPLIED TO AIR COMPRESSOR.

at cruising speed. The desideratum is, therefore, a turbine capable of performing economically at both cruising and full speed. The United States Government is now conducting extensive trials of this method of propulsion and the result will be publicly reported in the near future. The improvement which will be effected will be of the nature already denoted.

The reduction gear now brings the lake steamers and slow-going vessels within the domain of turbine application, and it is not unreasonable to presage that marine engineering will be revolutionised in the immediate future in a manner similar to that wrought by the turbine in stationary practice. There is, besides the mechanical application, the hydraulic and electric system which have been tried out in marine work, but these are inherently inferior in both operation and efficiency. The hydraulic or Fottinger gear has been tested in Germany, and within the last few months the United States Government has contracted for electrical equipment in order that competitive trials may be conducted and comparisons drawn with the geared outfit.

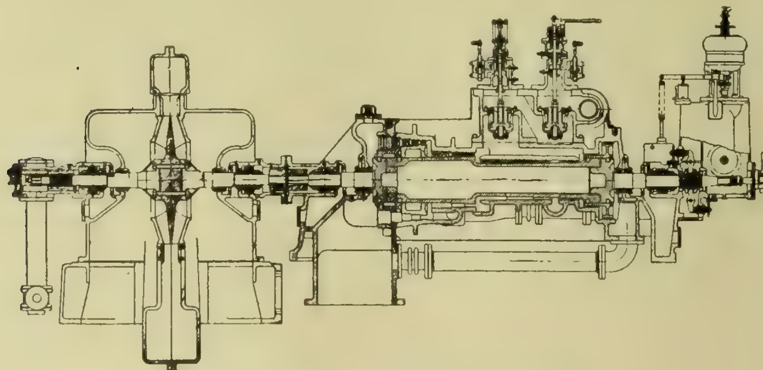


FIG. 18.—TURBINE AND CENTRIFUGAL COMPRESSOR.

Rolling Mill Service.—With the turbine now being used in the rolling mill by mechanical coupling to the rolls through gears, it has successfully encroached upon every important field of application of the reciprocating engine, with the exception of the reversing, hoisting, and rolling-mill service. While the reversing marine turbine is now an actuality, yet it is a problem whether the turbine will become a factor in stationary reversing work, especially in small sizes. As the matter is of direct interest in connection with the development of the large power reduction gear, the essential facts of the geared turbine rolling-mill installation of the Calderbank Steel Works, Scotland, are reproduced, together with a plan of the lay-out. These were discussed at length in a paper entitled, "The Application of a Geared Steam Turbine to Rolling Mill Driving," by Mr. A. Quentin Carnegie, published in the Journal of the West of Scotland Iron and Steel Institute, Vol. XVIII. In Fig. 16 is shown the general arrangement of the installation in elevation and plan. The steam turbine is of the Parsons mixed-pressure type and is designed to run at 2,000 revs. per minute.

"The mill runs at a speed of 70 revs. per minute, and the speed of the turbine is reduced from 2,000 revs. per minute in two steps, the intermediate shaft running at about 375 revs. per minute. Both pairs of gears are arranged in cast-iron gear cases, which are provided with suitable white metal lined bearings for the shafts. Flexible couplings are fitted between the turbine and the high-speed pinion shaft, and also between the first and second reduction gears. The couplings allow for small errors in the alignment of the shafts, and also give the necessary end freedom for expansion of the steam turbine shaft. The first slab was put through the mill on September 15th, 1910, after the whole plant had been run slowly for several days to allow the main bearing to settle down into working order. Up to thirty slabs have been rolled in an hour, and the maximum size of the plate has been 60ft. long by about 6ft. wide, with a minimum thickness of $\frac{3}{16}$in. The lifting tables for some time worked too slowly, but they have now been speeded up, and take six seconds for the lift and fall. The general experience which has been obtained with the working of this plant is sufficient to show that the experiment has proved a most gratifying success. The mill has been working regularly ever since the heavy bearings have settled down into good working order, and no

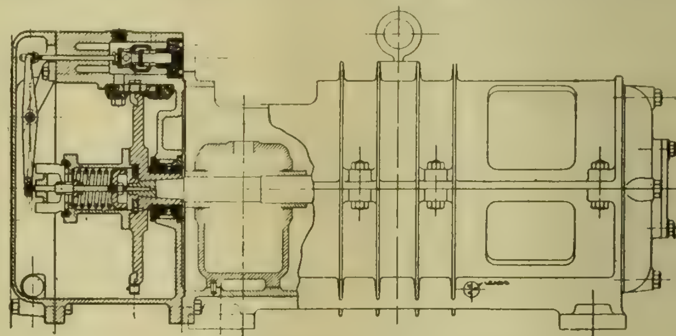


FIG. 19.—TURBO-ELECTRIC MACHINE, FOR LOCOMOTIVE HEADLIGHT.

trouble of any sort has occurred. Referring now to the future fields which these two important experiments have opened up, the writer sees no difficulty in applying turbines to the driving of textile mills or other works which require large powers. The geared turbine will easily give the absolutely uniform speed of drive on which advocates of electric driving for cotton mills based all their claims, and it will give this without the intervention of electrical machinery with its power losses and heavy capital cost."

Additional Fields of Application.—For the reasons which have made the turbine prominent in the applications previously mentioned, new fields have been constantly opening up for this interesting prime mover. Some important ones may be noted: (1) Low duty pumps; (2) Air or gas compressors; (3) Train lighting sets; (4) Locomotive headlights.

Air and Gas Compression.—One of the latest invasions into the stronghold of the reciprocating unit has been the building of high-pressure centrifugal compressors. In the past, neither the centrifugal pump nor compressor have been considered as being practical for high head work or pressure, owing to the poor showing made of the early types. The fundamental theory of centrifugal design has not heretofore been sufficiently understood and appreciated so that we are just awakened to the unusual possibilities of the centrifugal unit for this service.

Analysis of preceding constructions will show the entire lack of regard of the necessity of converting the kinetic energy represented by the final velocity into potential energy, so that 50 per cent. of the energy

was lost merely in this way without reckoning the other losses attending its operation. There are several methods of effecting this conversion, *i.e.*, diffusion valves, volutes of proper design, and diffusion tubes or inverted nozzles, and the application of these is governed by the nature and extent of operation. Hence with proper designs, efficiencies of 65 per cent. to 90 per cent. are obtainable. Details of a high efficiency compressor designed for moderate pressures are given in Fig. 17. Several single impellers (as shown) may be placed on a common shaft and operated in series, each imparting an equal amount of energy to the air, and thus serially building up the pressure. Each succeeding impeller raises the pressure to a higher degree than in the preceding stage, as may be quickly grasped in dividing up the compression

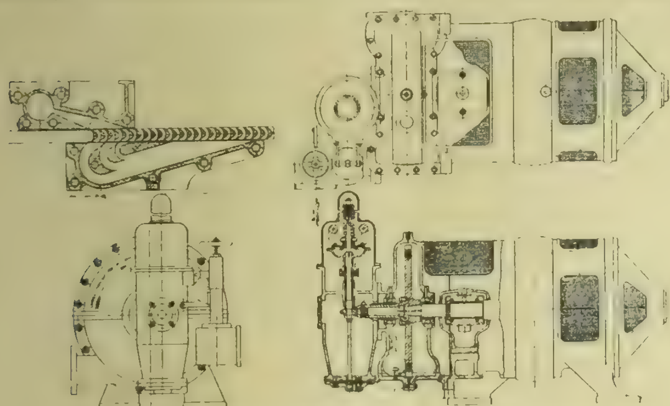


FIG. 20.—TURBO-ELECTRIC MACHINE FOR TRAIN LIGHTING.

card into equal divisions of work. Or, in other words, since the energy expended in each stage is the same, the pressure difference must be greater, inasmuch as the volume delivered to the following impeller is less, owing to its higher pressure. This follows from the formula $PV^n = K$. The noteworthy features of the multi-stage compressor is that the efficiency of the series of impellers is the average of each independent wheel; losses are not cumulative as may be supposed. Blowers of this type may be conveniently built in sizes impractical in the reciprocating design. Freedom from pulsations and vibration in the system is a large factor in their favour, and foundation requirements also may be found to be a weighty consideration. The other advantages, reduced attention, oil,

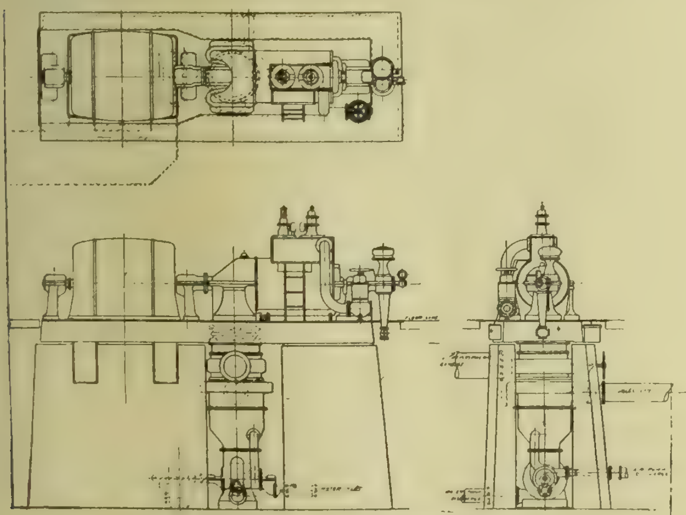


FIG. 21.—TURBINE CONDENSER APPARATUS.

and costs, are evident with centrifugal construction. Compressors of this type containing ten more stages are readily built for pressures of 80lbs. to 100lbs.

It so happens that the centrifugal compressor in Fig. 18 has been connected to a 700 h.p. reaction turbine of 3,600 revs. per minute, and is correspondingly represented by sectional detail. This is probably one of the most familiar of turbine sections to engineers in general, and there is warrant in remarking that for this capacity and speed the design has proved itself most efficient mechanically and thermodynamically.

Locomotive Headlighters.—There are certain railway systems, especially single-track lines, which require special safety measures in order to operate fast trains and maintain schedules. A most interesting application of the turbine responds to this small self-contained generating set, mounted on the engine, either above the boiler or on the pilot. This penetrating light may be distinctly observed, in a line of unobstructed vision, for a distance of over a mile at night, and the radius of the engineer's sight extends 3,000ft. ahead. Warning of danger ahead is therefore given in time to escape or avert accidents. It is no doubt understood by many that a number of States have enacted laws compelling trains to be equipped with an electric headlighting set, or other high candle-power lamp, and the greater safety along these highways is evident. Reliability is therefore most important, and the simplest and most dependable mechanisms are demanded. Fig. 19 illustrates how some of the designs previously described have been reduced to such a satisfactory state. All parts of the turbine and generator are totally enclosed and therefore weatherproof. The unit is but 3ft. in length and develops 1 kw. at 4,000 revs. per minute, using about 185lbs. of steam per hour.

Train Lighting.—Generating equipments driven from the axle of the car wheel have been used for this service, and possess some advantages, but are plainly very complicated and undoubtedly require a high degree of supervision to maintain them at reasonable cost. They are possibly best suited to trains making short local runs, and in any case, where the make-up of the train is subject to frequent change, to avoid making and breaking electrical connection between successive cars. The storage-battery outfit is the simplest

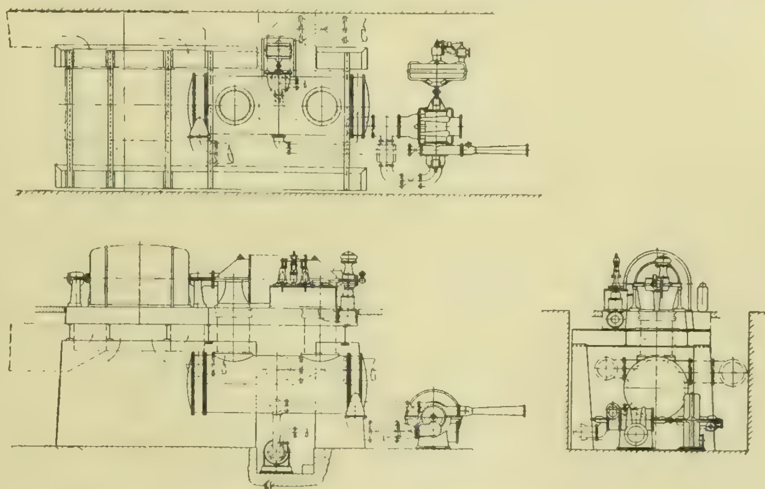


FIG. 22.—TURBINE-DRIVEN PUMPS FOR CONDENSING APPARATUS.

installation, but the chief objection to this type is to be found in the attention required and the provisions for charging necessary at the terminals.

Steam-driven generating sets are the next in simplicity, and probably form the most practical solution of the car-lighting problem. Reciprocating steam engines have been used to some extent, and while their economy in units of small size is somewhat superior to that of the turbine, the latter is to be preferred owing to its quiet operation. Units for such service are generally installed in the baggage car, and in the absence of heavy foundations the reciprocations of the engine may be felt throughout the entire train and have proved very annoying. The turbine, on the other hand, is inherently quiet-running, and, moreover, its small floor space requirements possess a real value in this particular service. A turbine-driven equipment, as shown in Fig. 20, would obviously prove best for long-distance "through" trains, all coaches being on one electrical circuit supplied from the single source.

The greatest advantage of the independent steam unit evidently lies in the possibility of maintaining continuous operation for any period, regardless of whether the train is in motion or at rest. This characteristic will be appreciated by those who have experienced prolonged delays in darkened cars.

Some New Types of Installations.—For straight condensing operation, Figs. 21 and 22 show economical layouts as regards piping connections and compact arrangement of condenser

and auxiliaries directly beneath the turbine, obviously avoiding their location in the path of travel. Fig. 22 is of particular interest, as it shows how simply and effectively turbine-driven air and circulating pumps may be applied to surface condenser work and the minimum floor space requirements.

In Fig. 23 is represented a typical layout of a central station equipped with an automatic bleeder turbine serving a combined heating and electrical load. As to be noted, the arrangement of piping is exceedingly simple, the exhaust and bleeding connection from each unit delivering into common headers which lead respectively to a central condenser and the heating system. In some installations it may be the desire to divert all the steam from the turbine into the heating system. If the turbine is fairly well loaded, as it probably would be under these circumstances, it would prove more economical to have the steam pass through the entire turbine, providing none escapes to atmosphere. This could

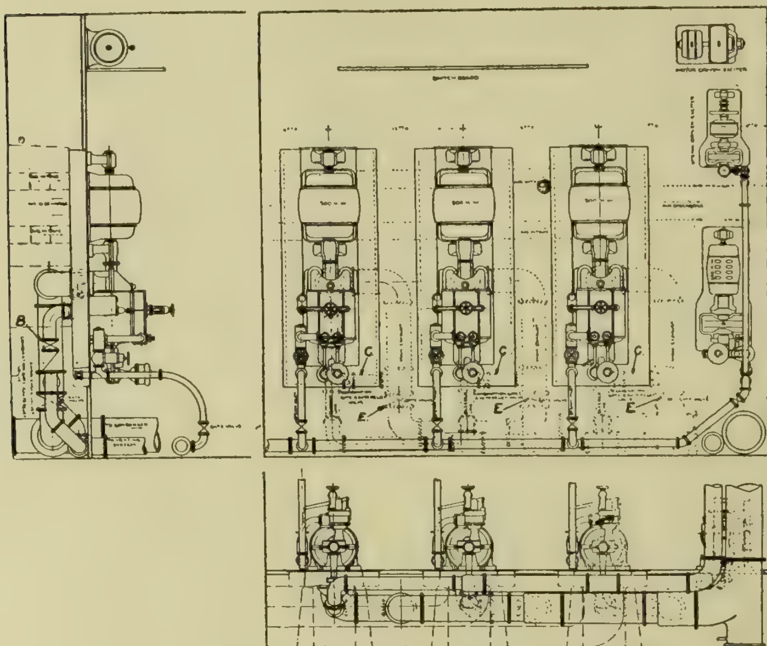


FIG. 23.—STATION LAY-OUT, WITH BLEEDER TURBINE.

easily be accomplished by introducing gate valves B and E in the main exhaust and bleeder lines from each turbine and the interconnection C. Then to run the low-pressure stage non-condensing, passing all steam to the heater system, valves B and E would be closed and the valve in connection C opened. With the automatic bleeding operation, as normally obtains, B and E are open and C closed. Operating strictly condensing, B and C are closed, E obviously being wide open, and the automatic valve on the turbine raised out of action.

The Institution of Mining Engineers.—The 23rd annual general meeting of this Institution will be held at Birmingham on Wednesday, September 11th, 1912, at 10-30 a.m., in the Lecture Theatre of the University, Edmund Street, Birmingham, when the following papers will be read, or taken as read: (1) "Recent Legislation in Relation to Land and Mines," by Mr. Alexander Smith, M.Inst.C.E.; (2) "An Account of a Series of Explosions in the Bellevue Mine, Alberta, Canada," by Mr. John T. Stirling, Chief Inspector of Mines, Alberta, and Mr. John Cadman, D.Sc. The following papers, which have already appeared in the Transactions, will be open for discussion: (*a*) "Why Leave Shaft Pillars?" by Messrs. W. H. and B. H. Pickering; (*b*) "Safety Devices in Connection with Electrical Machinery and Appliances for Coal Mines," by Messrs. David Bowen and W. E. French; (*c*) "A Rope-driven Coal Cutter," by Mr. Wilfrid L. Spence. Excursions have been arranged to the Mining Department of the Birmingham University, Bournbrook; The Earl of Dudley's Round Oak Iron and Steel Works and Baggeridge Colliery; the Cocoa and Chocolate Works of Messrs. Cadbury Bros., Ltd., and to other places of interest.

NARROW-GAUGE RAILWAYS.

IN the course of a paper, entitled "Rolling-stock on the Principal Irish Narrow-gauge Railways," recently read by Mr. R. M. Livesey, locomotive superintendent, Co. Donegal Railways Joint Committee, Stranorlar, before the Institution of Mechanical Engineers, the author recounted a few of the reasons for, and the relative advantages and disadvantages of narrow-gauge railways.

Practically, the only reason for the construction of a narrow-gauge line was, he remarked, cheapness, and no doubt in certain cases a considerable saving could be effected. But if, as in many instances in Ireland, such a railway had to be fully equipped, almost on the same lines as a broad-gauge railway, in order to comply with the somewhat onerous requirements of the Board of Trade, then there was very little to be gained from the point of view of economy. The author had in mind one narrow-gauge railway which cost £11,500 per mile, exclusive of rolling-stock, although there was no really heavy work involved in its construction. For all practical purposes, the only saving was in land, a narrower width being required, and this was comparatively small. No railway should be built of narrow gauge if the cost exceeded £5,000 per mile, and then only if the proposed line was for ever isolated from those of standard gauge, and the traffic always likely to be small. It would be decidedly better to build a "light" railway of the standard gauge. As the mileage of narrow-gauge lines in Ireland was no less than 525, of which nearly all was 3-feet gauge, it seemed regrettable, now that they had come to stay, that the majority of them were not linked up to form one large system. The whole of the stock might thus have been built to a uniform standard. No two lines had similar stock, nor would they be readily interchangeable; even the height of buffer centres varied in them all.

From the rolling-stock point of view, the disadvantages of a narrow-gauge line altogether outweighed the advantages, if any; and they could be summarised as follows:

(*a*) Steep gradients, due to following closely the contour of the country, in an effort to save money in banks and cuttings.
(*b*) Sharp curves due to similar causes.
(*c*) Greater overhang required, in order to provide reasonable accommodation, with consequent greater liability to overturn.
(*d*) Greatly reduced speeds.
(*e*) Great inconvenience and loss, owing to break of gauge when coming into contact with a line of the standard gauge.
(*f*) A certain amount of cramping of parts, and accompanied by reduced accessibility.

With regard to the first two items, it seemed that very little thought was given to future working when many of the lines were projected. A comparatively small additional outlay, in the first instance, employed in reducing grades and making easier curves, would have been repaid many times over by the savings effected in working. Heavy gradients and sharp curves were quite as objectionable from the point of view of working on a narrow-gauge as on a broad-gauge railway. These difficulties were practically insurmountable after the line had been made; but, in the case of items (*c*) to (*f*), they could be greatly minimised by careful design and a little forethought in working out details.

In the matter of the break of gauge, the difficulties of transhipment, in the case of goods and parcels traffic, could be greatly reduced by the employment of specially-designed tranship-trucks, some of which had been in successful use on the County Donegal Railways for many years.

The Irish narrow-gauge lines appeared to afford greater variety in the design of locomotives and other stock than did the broad-gauge railways; the general effect was pleasing, and there was no doubt that, apart from all idiosyncracies of design and appearance, the stock referred to did excellent work under very trying conditions. The only limits to the size of narrow-gauge engines, &c., were those imposed by the weight of rail in use, permissible loads on existing bridges,

and necessary clearance of existing structures. The gauge itself had little influence on the size of engine, if speed was restricted; the greater tendency to overturn on curves could be counteracted to a large extent by giving the outer rail ample super-elevation. This was relatively greater for the narrow-gauge than for the broad-gauge for the same speed. The comparatively high speed of 40 miles an hour was quite common on the more important narrow-gauge lines.

The type of engine almost universally adopted was the "side-tank." There were only two tender engines in use, namely, on the Londonderry and Lough Swilly Railway; and the Ballycastle Railway had a couple of "saddle-tank" engines. In the design of the earlier narrow-gauge lines, parts were frequently cramped and inaccessible, but, with experience and confidence in their possibilities, these defects were disappearing. One of the difficulties in the design of narrow-gauge engines was the firebox, especially in the larger types. Owing to the very restricted space between the wheels and to the fact that the length of firebox was fixed by the conditions of firing, namely, the difficulty of properly distributing the coal at a distance from the firehole, it was not easy to get a grate area sufficient to burn the requisite amount of fuel. If all the coupled wheels could be placed in front of the firebox, this difficulty would be disposed of; but in practice such a course was seldom feasible.

The form of the firebox in cross-section differed materially from that of a standard-gauge engine; the design, spacing, and position of side and roof stays required careful study and great experience, if trouble was to be avoided. Generally speaking, enough attention had not, he observed, been paid to this subject, one designer merely copying another, and consequently many such fireboxes were a continual source of anxiety to those in charge. The copper plate, in contact with the fire, usually suffered more severely in a narrow-gauge engine than in a broad-gauge, owing to this restricted grate area and to the greater blast pressure required in order to burn the necessary quantity of fuel in a limited time, with consequent severer scouring action on the plate surfaces. This involved higher temperatures, which had a serious effect upon the plates in a shorter time than would be the case on a standard-gauge engine. Tube plates suffered more severely from the same cause, and also from the greater frequency of the changes of temperature, as well as the greater range, which produced severer and more rapid reversals of stresses.

The author had had great experience of firebox troubles with narrow-gauge engines, and when abroad he experimented with Lowmoor iron and steel fire-boxes, with the result that the latter gave a considerably longer life than iron, and the iron than copper, where the water was exceptionally bad. All firebox troubles were ultimately eliminated by the introduction of a circular steel firebox, which gave every satisfaction and was very much cheaper in first cost.

In Ireland, outside cylinders only were the rule, as there was no room between the frames, and usually the latter were outside the wheels. This gave greatly enhanced steadiness in running. A leading four-wheel bogie was very generally used, though where the load per axle did not exceed the maximum permitted by the weight of rail, there was no reason why a two-wheel bogie or pony truck should not be used—provision of course being made for lateral movement—and so reduce the non-effective weight of engine.

The couplings in almost universal use were of the "central combined buffer and draw-hook" type; they were automatic couplers, very efficient, and perfectly safe. Frequently a considerable amount of side-play was provided in order to allow freedom and flexibility on curves, and on carriages a "slack gathering" apparatus was usually fitted; though there was no such fitting which could be regarded as sufficiently reliable and effective in its action. The screw-coupling in use by the Cork, Blackrock, and Passage Railway was certainly the best for this purpose. Experience, however, seemed to show that a slack gathering apparatus was not absolutely essential, at any rate on narrow-gauge lines with the central buffer. Side coupling-chains, as an additional precaution, were generally used, but on the County Donegal Railways they were not coupled, except when the draw-hook would not engage, as was sometimes the case on sharp curves in station yards; and the side chains then enabled the vehicles to be drawn on to the straight to allow of the buffer engaging properly.

There was little else in the design of narrow-gauge stock that presented any very special difficulties or that differed materially from the standard-gauge styles. In the working of the stock, particularly engines of the heavier type, more attention was required to be given to lubrication, and a larger quantity must be used in the case of narrow-gauge engines than in broad-gauge. It was generally and roughly assumed that a narrow-gauge engine, travelling at, say, 30 miles an hour, had its moving parts doing as much work as a standard-gauge locomotive running at 60 miles an hour. An example from actual practice would make the point clearer. The figures in the accompanying table were taken from a typical engine of the broad and narrow gauges respectively.

Obviously it would require a greater quantity of oil to lubricate 540 square feet of surface than it would for only 407 square feet; similar reasoning applied to other working parts. Attention was drawn to this point because it was often urged that narrow-gauge engines required considerably less oil than the standard engines. The difficulties of lubrication were enhanced, in the former case, by the greater proximity of the working parts to the ground and to the consequent easier access of dust and grit to the working parts; this was especially the case in dry summer weather, and in some instances it was necessary to close in the motion work entirely to protect it from injury.

	Broad-gauge Engine.	Narrow-gauge Engine.
Diameter of driving wheels	6ft. 6in.	3ft. 9in.
Revolutions per mile	258½	448
Diameter of journals	8½in.	8½in.
Length of journals	8½in.	6½in.
Pressure on journal (lbs. per square inch)	201	202
Lineal movement of circumference of journal per mile	575ft.	997ft.
Surface swept by journal per mile...	407 sq. ft.	540 sq. ft.

It need hardly be stated that the power required to haul a given load was independent of the gauge, and the cost would be the same for any gauge. Any advantage in cost to the narrower gauge, where it existed, was due to the relatively lesser tare weight of vehicles and slower speeds, and not to the gauge. On the larger and more important of the narrow-gauge lines in Ireland the carriages and wagons would accommodate quite as much traffic, of the same volume and weight as the broad-gauge vehicles, and in some cases more so, yet the tare of the former was considerably less. The wagons of the County Donegal Railways would all carry a net load of 7 tons, and the average tare of each was 3¾ tons, though all were equipped with both hand and vacuum automatic brakes; they were very substantially built and were capable of being run at any speed. The present standard six-compartment carriage of the same railway accommodated 60 people comfortably, was fully equipped with vacuum automatic brake, with acetylene lighting plant, &c., and weighed only 11 tons 14 cwt., or 3·9 cwt. per passenger.

For the reasons just enumerated, the narrow-gauge stock was relatively much more efficient than the broad-gauge; in other words, the proportion of paying to non-paying loads was considerably higher, and some authorities put this figure at from 12 to 15 per cent. The foregoing remarks were not put forward as showing the advantages of a narrow-gauge line, but served to show where economy could be effected by judicious reductions in the scantlings and weights of broad-gauge vehicles.

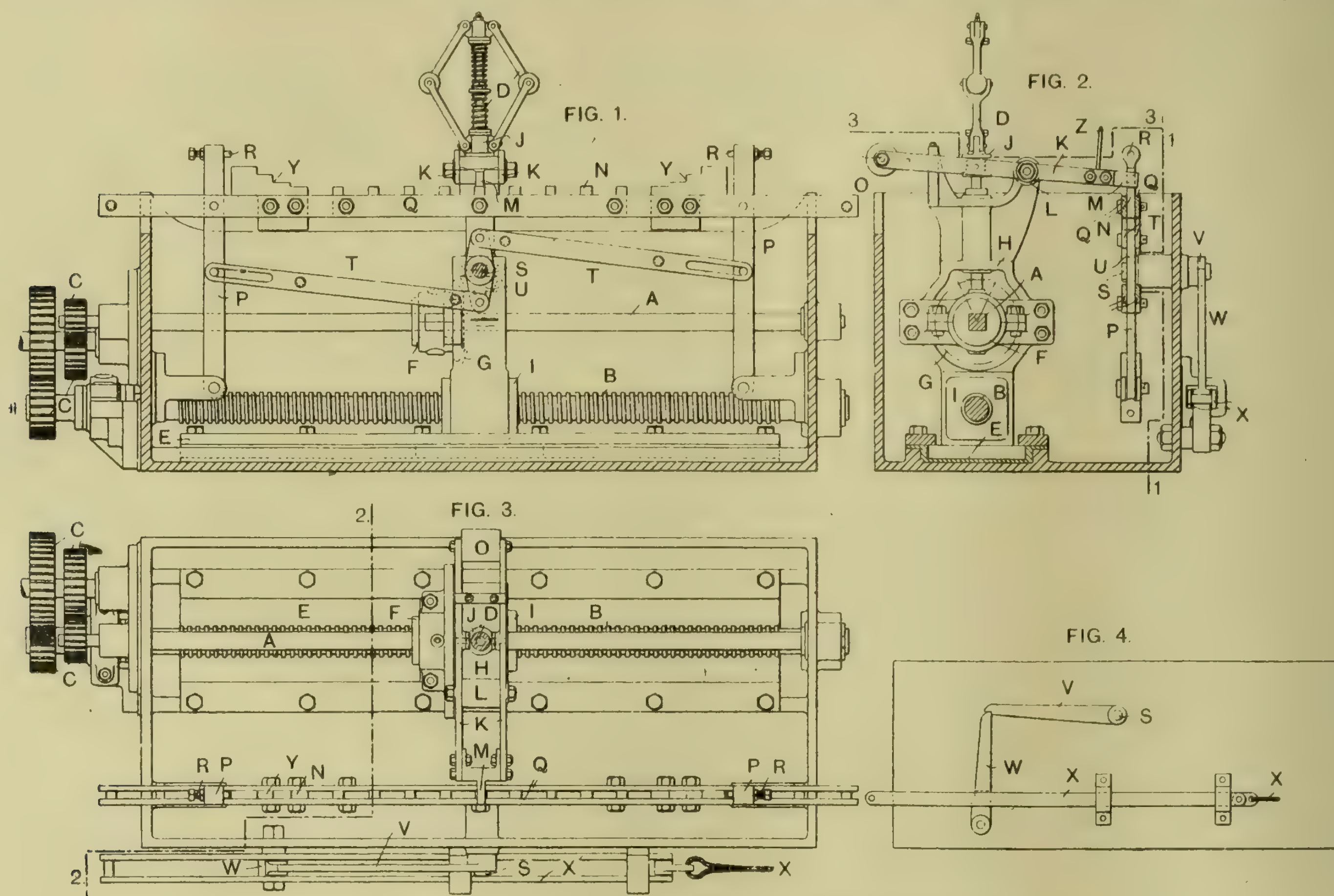
A Large Storage Battery.—What is said to be the largest storage battery in existence has been installed as a stand-by for the Consolidated Gas, Electric Light, and Power Company, of Baltimore. The battery consists of 152 cells, each containing 133 plates, and the total weight is 616½ tons. It is capable of delivering 44,000 amperes at 250 volts for 6 mins., equal to an output of 11,000 kw.

INGLIS SPEED-CONTROLLING GEAR FOR PREVENTING OVERWINDING IN MINES.

The accompanying illustrations show an arrangement of engine speed-controlling gear for preventing overwinding in collieries, the invention of Messrs. G. Inglis & Co., Ltd., Albert Engineering and Boiler Works, Airdrie, Lanarkshire. Figs. 1 and 2 are sectional elevations at right angles to each other taken respectively on the lines 1—1 in Fig. 2 and 2—2 in Fig. 3 which is a sectional plan view taken on the line 3—3 in Fig. 2. Fig. 4 is a front elevation of a detail.

The box or housing frame carries a horizontal square shaft A with journals at each end and having extensions at one or both ends for fixing spur wheels C. There is also used in combination with the aforesaid a horizontal screw shaft B with thrust bearing, and having extensions at one or both ends for mounting corresponding spur wheels C. The governor D hold a vertical arm W in position to which the weighted rods or ropes X are attached that actuate the brakes and the throttle valve. The whole arrangement may be operated either by gearing and shaft from the engine or by a pitched chain or equivalent devices from the shaft of same.

The working of the gear is as follows: When the winding engine starts a wind, the governor D is moved along the box by the screw shaft B and the speed part of the governor is driven by the square shaft A. If the engine attains a higher speed than that predetermined, then the governor sleeve J rises and depresses the one end of the double lever K and catch M and causes this catch to come in contact with the rack N. It will be readily understood that as the governor D is travelling (in either direction) and the catch M coming into contact with the rack N the shaft S will be partially rotated by means of wyper P and connecting rods T and lever U, and the trigger or trip lever V will release the arm W holding the weights so that the steam is immediately shut off,



INGLIS SPEED-CONTROLLING GEAR FOR PREVENTING OVERWINDING IN MINES.

is driven by the square shaft A which revolves a sleeve F to which a bevel wheel G is attached. In the lower part of body H is a screwed nut I into which the screw shaft B works so as to travel the governor D from end to end of the box, the weight of the governor being carried on the guide E. To the rising and falling sleeve J of the governor D is attached a double lever K, supported in a fulcrum L, and projecting beyond the fulcrum on the one side and beyond the governor on the other side. On the side beyond the fulcrum is fixed a steel catch M to engage with a toothed rack N, and on the other side of the governor D a balance weight O is attached by a pin and slot and made so that its position can be adjusted to suit the requirements of the governor D. At each end of the box, at one side, is fixed a perpendicular arm or wyper P working on a pin at bottom and joined together by two flat bars Q, one on each side, with pins holding them together. Between these two bars is fixed a rack N over which the double lever K and catch M passes as the governor D travels along the box in either direction. The wyper P at each end is fitted at top with a set screw R facing the direction of the travel of the governor D, and this set screw can be adjusted to suit varying stopping conditions. To the rack N and wypers P is fitted a shaft S, double-ended lever U, and connecting rods T with slots, and to this shaft S a trip lever V (Fig. 4) is secured to and the brakes applied, and the engine stopped. If towards the end of the wind the engine has not been reduced in speed to what is considered safe at that part of the wind the catch M comes in contact with a higher stepped part Y of rack N and releases the trigger and stops the engine as previously described. Should the engine be started in the wrong direction, the catch M of the lever K at once comes in contact with the set screw R at top of wyper P. This releases the trigger and the engine is stopped in like manner. The end of the lever K which bears over the rack N is weighted by mounting portable weights on the pin Z so that the speed at which the rack and the trip devices is actuated may be regulated.

Steam Consumption of Locomotives.—According to a correspondent of the "Railway Gazette," the average steam consumption of the locomotives engaged in working the principal express passenger services of the London and North-western Railway is 56lbs. per mile. This figure refers only to the non-superheated "Precursor" type engines. The superheater locomotives of the same general pattern, he says, consume only about 38lbs. per mile, while for the run between London and Holyhead their consumption has been as low as 34½lbs. per mile as a monthly average.

THE STATUS OF THE GAS PRODUCER IN THE UTILISATION OF FUELS.*

BY ROBERT HEYWOOD FERNALD.

THE composition of producer gas varies greatly. The type of producer, the method and skill used in operating, the uniformity and the regulation of the air and steam supply, the kind and quality of the fuel used, the depth of the fuel bed, the distribution of the fuel, and the uniformity in size of the fuel are factors that affect the product. Inasmuch as the investigations involved in this discussion relate almost entirely to bituminous coal, lignite, and peat, the following typical analyses of up-draught and also of down-draught producer gas generated with these several fuels in a pressure-producer plant are given below. Percentages are by volume:—

Typical Analyses of Up-Draught Pressure-Producer Gas.

Constituents.	From Bituminous Coal.	From Lignite.	From Peat.
Carbon dioxide (CO_2).........	9·84	10·55	12·40
Oxygen (O_2)......................	·04	·16	·00
Ethylene (C_2H_4)	·18	·17	·40
Carbon monoxide (CO)	18·28	18·72	21·00
Hydrogen (H_2)	12·90	13·74	18·50
Methane (CH_4)	3·12	3·44	2·20
Nitrogen (N_2)	55·64	53·22	45·50

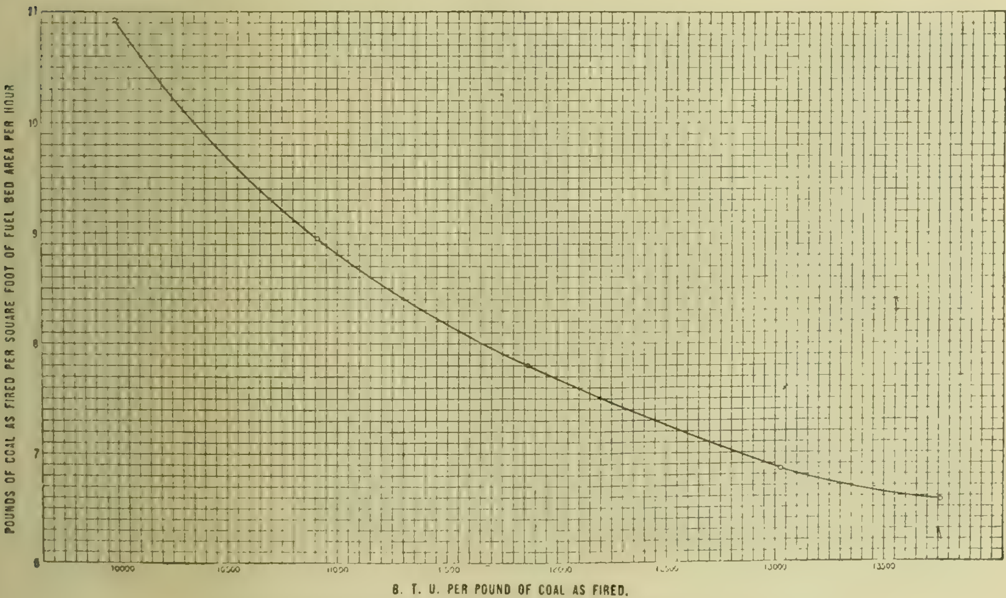


FIG. 1.—RELATION OF RATE OF FIRING TO CALORIFIC POWER OF FUEL.

Typical Analyses of Down-Draught Producer Gas.

Constituents.	From Bituminous Coal.	From Lignite.	From Peat.
Carbon dioxide (CO_2).........	6·22	11·87	10·94
Oxygen (O_2)	·13	.01	·41
Ethylene (C_2H_4)...............	·01	·00	·06
Carbon monoxide (CO)	21·05	16·01	16·91
Hydrogen (H_2)	12·01	14·76	10·19
Methane (CH_4)	·49	·98	·66
Nitrogen (N_2)	60·09	56·37	60·83

Carbon monoxide, hydrogen, ethylene, and methane are desirable constituents in producer gas, and the suitability of the gas for a particular industrial application depends somewhat on the relative proportions of these constituents. Producer gas with a high percentage of hydrogen may be well adapted to certain metallurgical applications, but if the gas is to be used in internal-combustion engines the percentage of hydrogen must be kept within certain limits. For this reason the methods of operating producer plants for the generation of gas for power purposes are often quite different from those employed where the gas is to be used for metallurgical work. In order to make producer gas suitable for use in an engine the gas must be thoroughly scrubbed and cleaned and be sent to the engine at a low temperature. Lowering the temperature increases the density of the gas, so that a given volume contains a larger number of heat units, and can develop more power in the engine.

Broadly, producer gas has two general applications—for power purposes and for metallurgical work. Three distinct types of gas-producer plants have been commercially manufactured, as follows: (*a*) Suction type, (*b*) pressure type, and (*c*) down-draught type. Besides these three a combination of the principles of up-draught and down-draught has recently been brought forward in the double-zone producer.

Producer gas has for years been extensively used in various types of furnaces in the manufacture of iron and steel. This use has become more and more general during the last few years. In the manufacture of producer gas for metallurgical processes the gas goes to the furnace directly from the producer without any cooling or cleaning.

Among the uses to which producer-gas fuel has been put are annealing, japanning, enamelling, tempering, case-hardening, type-casting, yarn singeing, cooking, and the heating of moulds, wash kettles, ladles, stoves, and bakers' ovens. It has also been used quite extensively in brick, lime, and cement kilns, and in various types of ore-roasting furnaces.

In using producer gas as a fuel, one should remember that the heat value of the gas is low compared to that of the other gases that are used for similar purposes, except blast-furnace gas. Natural gas has an approximate average heating value of 1,000 B.T.U. per cubic foot; the heating value of artificial or ordinary city gas is about 650 B.T.U. per cubic foot, whereas the heating value of producer gas ranges from 100 B.T.U. to 275 B.T.U. per cubic feet, according to the method of production. In spite of its low heating value producer gas is usually cheaper for work requiring relatively large quantities of gas than any other fuel, with the possible exception of natural gas sold at a low price.

In lime burning it is claimed that greater economy is obtained with producer gas than with coal, and that the output of a plant is considerably increased. The heat produced by the gas is readily controlled, and it is claimed that the flames from burning gas are perfectly adapted to the process. Owing to the absence of ash and clinker a much cleaner and purer product is produced, and the labour required is reported much less than that necessary with solid fuel.

In forge work the substitution of producer gas for oil, illuminating, and natural gas is developing, although special care is necessary regarding the methods of application. The substitution of producer gas for coal in cement burning seems to offer an attractive field. It is claimed that excellent economy is obtained, that a high-grade, uniform clinker is produced, and that the ease of control, the simplicity of the equipment, and the low cost of the installation and upkeep make producer gas an ideal substitute for coal.

The peculiar characteristics of the suction producer plant practically limit fuels for this type of installation to those containing little or no tar. Hence anthracite and semi-anthracite coal, coke, and charcoal are the principal fuels used. The standard types of suction producer are designed to use these fuels in what is commonly known as pea size. If very

* Abstract of Technical Paper 9 of the United States Bureau of Mines, Department of the Interior.

small coal is to be used, such as rice, barley, or fine screenings, or coke breeze, special producers are usually required.

Anthracite is the standard fuel for suction producers, and under certain conditions it is an excellent fuel. There are a great many power plants in daily use requiring attention not over two or three hours a day, that are as reliable as any steam-engine plant of the same size, and are far more economical. On the other hand, there are many installations that require attention practically all the time, and even then are frequently shut down. The troubles of these plants are often traceable to serious clinkering which may be due to the behaviour of the coal under certain temperature conditions, and may be unavoidable in plants of the ordinary construction. However, in many instances clinkering and a bad condition of the fuel bed are caused by an overload or excessive demands upon the plant. For the most part these overload conditions are undoubtedly due to an over-rating of the producer by the manufacturer. This fact has already been recognised by some makers, with the result that the guaranteed rating of their plants has been reduced 25 per cent. for the same area of fuel bed.

Even with the same working conditions much less difficulty is experienced with one grade of anthracite than with another. It is doubtful, however, whether sufficient study has yet been made to warrant drawing fuel specifications that will guarantee practically no difficulty in producer plants of the suction type.

In handling these suction producers it is necessary to keep the grates free from clinker and ash in order to facilitate the

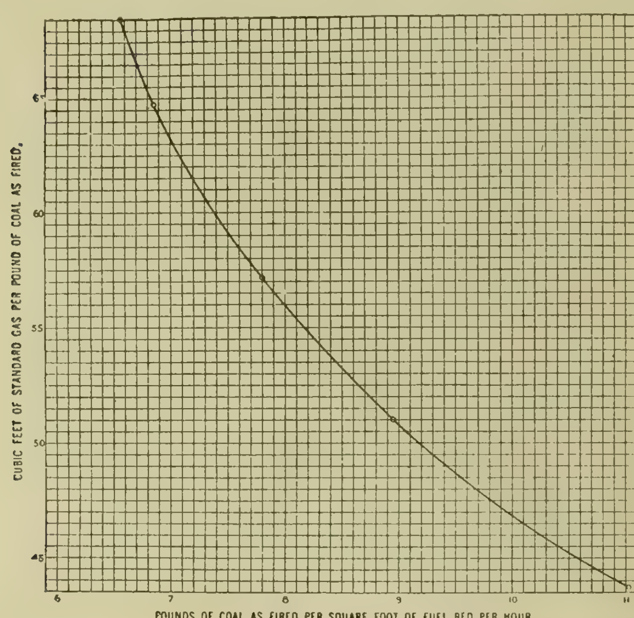


FIG. 2.—RELATION OF VOLUME OF STANDARD GAS GENERATED TO RATE OF FIRING.

action of the engine in producing the necessary draught, and to keep a clean fire a great many operators rake out considerable partly burned coal. It is the custom in many plants to throw this partly burned coal back into the producer. Though this practice is satisfactory in some cases, yet with certain kinds of anthracite it facilitates clinkering. As a result, the practice has been abandoned in some installations and the partly burned material, or coke, is saved for use in fireplaces or kitchen ranges.

Coke gives much more trouble from clinkering than anthracite and its use necessitates taking a longer time to get the producer into operation in the morning. after a standby overnight. Because of the price of anthracite, some people advocate using a mixture of anthracite and coke. Many operators claim that the best results are obtained with coke when it is crushed to walnut size.

Many efforts have been made to develop suction plants that will prove commercially profitable in the use of the tarry fuels, such as bituminous coal, lignite, and peat. Considerable success has been attained both in Europe and the United States with the use of lignite in suction producers.

Among the most interesting producer-gas plants in Europe are those burning peat. The application of small peat-burning producer plants for generating power has become general in Europe, although the first plant of this type was installed only five or six years ago. Before it is charged into the producer, air-dried peat, containing about 25 or 30 per cent. moisture, is passed through a crusher and broken into pieces 1in. to 4in. diam.

The operation of the suction producer on bituminous coal has been attempted by nearly all producer plant manufacturers, and the demand for small power units to operate on bituminous coal is large. Little success has been attained in the United States in meeting this demand, but in Europe the leading manufacturers are nearly all working on the problem, and each one has some form of plant that he feels is well adapted to bituminous coal. Limitations are, however, imposed abroad; that is, special restrictions are placed on the types of fuel that may be used. One manufacturer states that the bituminous coal used in a suction plant of his design must be of good quality, low in ash (8 to 10 per cent. as a maximum), and non-caking, and must not contain more than 7 per cent. tar. The same idea is expressed by another manufacturer, who says that for coals other than anthracite he confines his attention to short-flaming, low-ash coals that do not cake and make little tar. To satisfy these limitations three varieties of coal are often required, mixed in proper proportions. All fine coal is sifted and the dust thrown out to prevent matting. Under similar restrictions it is difficult to see how such plants can meet commercial demands.

The range of fuels that can be used in either the pressure or down-draught plants is much greater than that for the suction plant. All of the fuels mentioned for the suction plant, considered purely for their gas-making qualities, are available for use in these installations. The price is the principal controlling factor.

The development of the crude-oil gas producer, for which there is great demand in oil regions remote from the coalfields, has been exceedingly slow, but there is reason to believe that decided progress has recently been made. The most recent notes on this subject relate to the Grine oil producer. In this type of producer a steam spray is used for atomising the oil which is introduced into the upper part of the generator where partial combustion takes place. The down-draught principle is then applied and hydrocarbons are broken up and the tar is fixed by passing through a bed of incandescent coke. A power plant using one of these producers has been in operation a year in California. With crude oil as fuel, costing 95 cents per barrel, or 2·3 cents per gallon, the plant is reported to develop the same power per gallon of crude oil as is ordinarily developed by the standard internal-combustion engine operating on distillate at 7 cents per gallon. Including the cost of fuel, labour, supplies, interest, depreciation, and taxes, the cost per brake horse-power hour is stated to be 0·76 cent for a plant of 100 h.p. rating.

Besides the fuels previously mentioned, producers have been operated on wood, sawdust, tanbark, straw, hay, corncobs, cornstalks, and even leather scraps, but these fuels, with the possible exception of wood and sawdust, have not come into general use.

It is customary at the present time to designate the capacity of gas producers in terms of horse-power. As is the case with boilers, however, this usage is a misnomer, since there is no such thing as the horse-power of a producer. The expression strictly means the size of producer that will uniformly supply an engine of a given horse-power rating with gas over a considerable period of time; that is, a 250 h.p. producer means one that will supply sufficient gas to operate an engine rated at 250 b.h.p. for several consecutive hours under full load.

From the general discussion on gas-producer fuels it will be seen that the quantity of fuel that can be burned in a given gas producer per hour and the quantity of gas that can be generated will vary widely according to the kind of fuel used. This point is perhaps made clearer by Figs. 1 and 2, which show the rate of burning of a large variety of fuels in a producer of the dimensions necessary to develop sufficient gas to operate a 235 b.h.p. engine at full load. A wide difference will be observed in the required rates of fuel consumption between the coals of high heat value (14,000 or more B.T.U. per pound) and those of low heat value (between 7,000 and 8,000 B.T.U. per pound).

Again, it is obvious, from a study of the curve shown in Fig. 1, that if the rate of burning the high heat value coals be

increased to that of the low heat value fuels, the volume of gas generated will be large enough to supply an engine of much more than 235 h.p. In other words, the producer that would be called a 235 h.p. producer with one fuel might be rated as 300 h.p. with another fuel and 400 h.p. with another.

For metallurgical and furnace purposes in which no engine is employed there is no definite relation between horse-power and producer size. In general, then, a better method is to designate producers by the diameter of the fuel bed and the rate of burning the fuel per square foot of fuel-bed area.

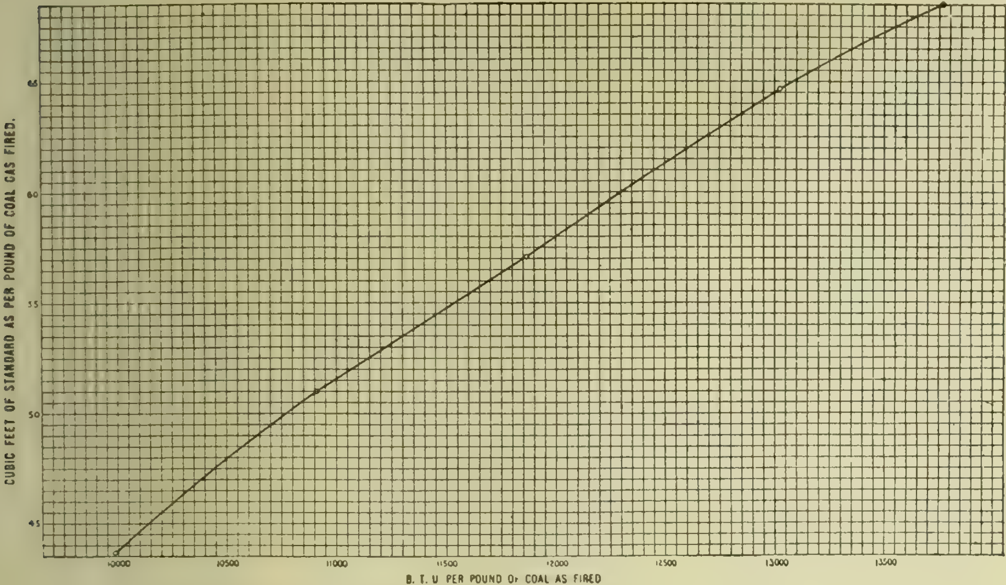


FIG. 3.—RELATION OF VOLUME OF STANDARD GAS GENERATED TO CALORIFIC POWER OF FUEL.

The rate of fuel consumption is an uncertain factor and has led to much difficulty in designing and in rating producers. Early work in the United States followed European practice almost entirely, and thereby occasioned a great deal of trouble in properly rating the plants and brought about the ultimate failure of many of them. Under European conditions, in which fuels of a certain grade are specified, high rates of fuel consumption may be obtained. Similar rates are not impossible under corresponding circumstances in the States, but as such conditions seldom prevail, it has been found that in general the rate of fuel consumption per square foot of fuel-bed area does not average much over half the amount originally guaranteed by the early manufacturers. This fact has, of course, led to a decided modification in the design and proportions of many plants. Even to-day there is some tendency to over-rate producers, especially those of the suction type. Such over-rating is not only likely to make trouble in adjusting the purchase price of these plants, but usually results in serious operating difficulties if the installation is worked at or near its capacity. It has been observed frequently that a given plant using anthracite of good quality will have no operating difficulties when working up to 50 or 75 per cent. of the rated capacity of the producer, but if the producer is forced to its full rating for any length of time, clinkering and other troubles are encountered. These are often sufficiently serious to necessitate a reduction in load at a time when such a reduction is most inconvenient.

Although the rate of burning high-grade coal may be materially increased over that indicated in Fig. 1, such an increase is not always possible. A great deal depends upon the character of the fuel, and especially upon the nature of the ash. If the ash is highly fusible, it may cause such serious trouble from clinkers that the rate of fuel consumption will be decidedly restricted, whereas, on the other hand, the character of the ash may be such as to allow a high fuel consumption. The possibility of obviating all trouble from clinkering and ash accumulation, and permitting plants to operate continuously, is receiving attention in the attempt to maintain high fuel-bed temperatures and to remove the ash in the form of molten slag.

Certain types of fuel, such as lignite, permit a high rate of fuel consumption, especially in producers of the down-draught type. Plants are in operation that consume more than 40lbs. of lignite per square foot of fuel-bed area per hour, but the majority of producers do not gasify ordinary fuels at any such rate. It is true that suction and pressure producers may be made to gasify comparatively large quantities of fuel per hour for relatively short periods, but in actual operation with ordinary grades of fuel it is doubtful if the consumption exceeds 15lbs. to 16lbs. per square foot of fuel-bed area. The normal figure seems to be much nearer 10lbs., although, of course, some variation should be allowed for the "workability of the fuel." Even 10lbs. may be a high figure in the case of fuels having a large percentage of ash or a sulphur content that tends to produce serious clinkering.

The depth of the fuel bed carried in various plants seems to differ considerably. It is essential to have the fuel bed at all times deep enough properly to reduce carbon dioxide to carbon monoxide. It is also important that the fuel bed be deep enough to prevent excessive heating and burning of the gas and the formation of large channels by the draught. The proper depth of the incandescent zone will of necessity vary materially with the character of the fuel, but in general will be from 2ft. to 4ft.

The quantity of producer gas derived from a ton of fuel varies according to the fuel used, the type of producer plant, and the method of operation. At the Government fuel-testing plant at St. Louis the number of cubic feet of gas produced from various fuels in an up-draught pressure producer per pound of fuel was as follows:—



FIG. 4.—RELATION OF WEIGHT OF COAL USED PER B.H.P. HOUR TO CALORIFIC POWER OF FUEL.

Quantity of Gas Produced per Pound of Fuel in an Up-draught Pressure Producer.

Character of Fuel.	Average.		Maximum.		Minimum.	
	As fired cub. ft.	Dry cub. ft.	As fired cub. ft.	Dry cub. ft.	As fired cub. ft.	Dry cub. ft.
Bituminous coal..	60·5	64·7	100·8	103·5	37·0	40·9
Lignite	35·8	45·7	45·9	52·8	26·1	38·8
Peat	30·3	38·3	—	—	—	—

The relation of this gas production to the calorific power of the fuel is shown in Fig. 3. Based on the above averages the yield of gas, in cubic feet per pound of dry fuel, that may be expected from various fuels in this type of producer, is roughly as follows: Coke or charcoal, 90; anthracite, 75; bituminous coal, 65; lignite, 46; and peat, 38. On the basis of the Government tests the gas yield and the heat value of the gas per ton of fuel as fired are approximately as follows:—

Yield and Heat Value of Gas per Ton of Fuel as Fired in an Up-draught Pressure Producer.

Character of Fuel.	Yield of Gas per Ton of Fuel as Fired cub. ft.	Heat Value of Gas per cub. ft. B.T.U.	Heat Value of Gas per Ton of Fuel as fired B.T.U.
Coke or charcoal	170,000	140	23,800,000
Anthracite	140,000	135	19,000,000
Bituminous coal	120,000	152	18,300,000
Lignite	72,000	158	11,400,000
Peat	60,000	175	10,500,000

One of the fundamental reasons for the rapid development of gas producer plants is the low fuel consumption of these plants per horse-power hour. The consumption varies considerably with the heat value of the fuel, but the St. Louis tests show that even for the low-grade fuels the relative consumption is low, as indicated in Fig. 4.

UTILISATION OF PEAT IN GAS PRODUCERS.

OWING to the very large proportion of water contained in peat, it is impossible to utilise it in a gas producer without first drying it, wholly or partially. Several methods have been devised for accomplishing this, but owing to their heavy cost they have not been adopted to any extent. Another method which has recently been patented by D. Civita, 82, Corso Magenta, Milan, Italy, consists in passing the hot products of combustion of the gases from the producer over or through the peat after it has been dried by pressure or by disintegration and subsequent drainage, as far as is practicable. These products of combustion may be the flue gases from steam generators, the exhaust gases from some form of internal-combustion engine, or the waste gases from a heating furnace. As they are comparatively small in volume but at a higher temperature than is necessary, it is more economical to dilute them with air before they are passed through the peat. In practice it is found that when the gases have passed through the peat they will contain sufficient heat to raise the steam or part of the steam required for the blast of the producer when the latter is to be worked with recovery of ammonia.

The freshly dug peat is placed on a conveyer band and delivered directly into a Kraus machine, which is a bottle-shaped vessel having parallel screw shafts rotating in its wider part so that they break and forward the peat, fed into the vessel at the wide end, and discharge it at the narrow end. The broken peat is conveyed to the place in which the producer plant is situated and is dumped into a pit where it is allowed to remain for a couple of days or longer, during which time a considerable portion of the water in it drains away. From the pit the peat is elevated to a second Kraus machine which delivers the partially dried peat in the form of lumps about the size of a fist. These are received on wire gauze trays which when filled are placed in trucks for passage through the drying chamber.

The drying chambers are arranged in parallel (see Figs. 1 and 2). Each chamber consists of a brickwork tunnel A of a length adapted to receive seven of the trucks B, and of a cross-section slightly larger than that of the trucks. In Fig. 1 it is assumed that the trucks enter at the left-hand end and leave at the right-hand end, each end being closed by a door except when a truck is passing. The mixture of air and hot products of combustion is forced under pressure into a main C serving a number of adjacent chambers, and is distributed by pipes D which connect with horizontal flues E in the walls between the chambers. These flues are substantially of a length corresponding with the length of the chamber occupied by two trucks and communicate with the interior of the chambers through ports F so that the mixture of air and hot products may be evenly distributed at this end of the chamber. At the other end of the chamber the moist gases pass away through a flue G at such a temperature that they may still be used in any known apparatus for raising steam for use in the blast supplied to the producer. To the latter the dried peat may be delivered directly it leaves the chamber.

The method described may perhaps be best appreciated by referring to a specific case, namely, an electric power station worked by producer gas engines. The peat from the bog contains, say, some 88 per cent. of water. The process of comminution and storage in heaps reduces this to 75 per cent., but it is found impossible to use this peat profitably in the producer unless the water is reduced to 50 per cent. Each truck B carries about 2·2 tons of peat containing 75 per cent. of water, arranged on 15 trays H. Each chamber contains seven trucks and one truck is removed and one introduced every $1\frac{1}{2}$ hours. For seven such chambers operated in parallel, a blower absorbing about 70 h.p. is used and the products of combustion fed to this blower are mixed on their way with so much air that the temperature of the mixture is about 105° C. Under these conditions it is found that about

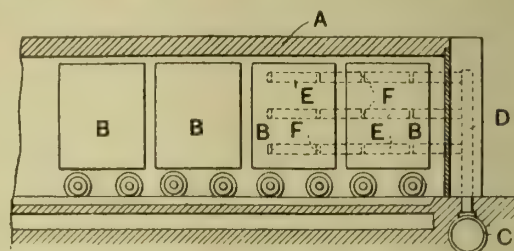


FIG. 1.

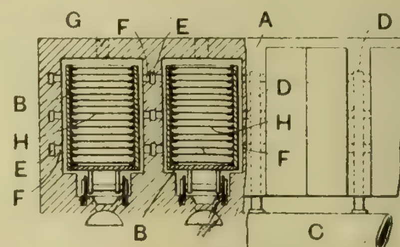


FIG. 2.
APPARATUS FOR DRYING PEAT FOR USE IN GAS PRODUCERS.

350 calories contained in the hot gases remove from the peat one kilo of water. This is explained by the fact that only part of the water contained in the peat is carried away as vapour, the rest being either carried as water in suspension by the gases, or condensed before the latter leave the chamber. It is found that the hot gases blown into the chamber and coming into contact with the moist peat, are gradually saturated and their temperature decreased as they travel onwards, till when they reach the fourth or fifth truck they are fully saturated at the temperature they have attained at that point. In passing through the succeeding two or three trucks of wet peat, the temperature of these gases still diminishes very considerably, but the short time occupied in travelling through these trucks prevents any water vapour from being condensed, so that the gases become super-saturated, while the heat they lose in passing through this peat is transferred to the peat. The last two or three trucks of peat in the chambers act as condensers, for it is found that a very considerable amount of water is deposited both on the surface of the wet peat contained in these trucks and on the trucks themselves. The liquid water drops freely from these trucks, and a water drain has to be provided at this end of the drying chamber to carry away the water in the same direction as the gases.

Man Killed by Collapsing Crane.—A workman was killed on the 28th ult., while operating a steam crane at Jackson's quarries, Britannia, near Bacup. The man, it appears, was winding a piece of stone weighing about seven tons, and when the stone was near the top he seems to have changed the gearing. The stone began to descend to the delph, when suddenly the crane collapsed. Part of the machinery broke a steam pipe, causing a dense volume of steam to escape. As a result, the man was so seriously injured that he died on the way to the Infirmary.

BRITISH ASSOCIATION.

PRESIDENTIAL ADDRESS TO THE ENGINEERING SECTION.

BY PROF. ARCHIBALD BARR, D.SC.

ONE of the great engineers of the past, Leonardo da Vinci, prefaced a collection of observations on various themes, including the Mechanical Arts, with the remark: "Seeing that I cannot choose any subject of great utility or pleasure, because my predecessors have already taken as their own all useful and necessary themes, I will do like one who, because of his poverty, is the last to arrive at the fair, and not being able otherwise to provide himself, chooses all the things that others have already looked over and not taken, but refused as being of little value. With these despised and rejected wares—the leavings of many buyers—I will load my modest pack and therewith take my course." These words describe, with some approach to exactitude, the position in which I find myself, and may form a fitting introduction to an address that will be discursive rather than systematic, and perhaps more critical than constructive.

It may be less true to-day than it was four hundred years ago to say that all important matters concerning the existing state of the mechanical arts have been dealt with in spoken or written addresses. Each year there might be found sufficient subject matter for a general survey of the ground that has been covered or a sketch of what lies before us. But each important advance is nowadays recorded as soon as it is made, and I do not feel that I have any special call to assume the rôle of the historian, nor can I claim any right to don the mantle of the prophet.

A president of this section, who is not disposed to deal with the general aspects of the progress being made in the department of science allotted to us, can usually find a large enough subject for his address within the limits of that part of our wide field with which his own work has been more particularly identified, and it might be expected that I would devote my address to a discussion of the conclusions at which I have arrived during 36 years of practice and experience in the teaching of mechanical science. But so much has been said of late on the training of engineers, and so many divergent and even irreconcilable opinions have been expressed regarding the lines such training should follow, that I feel sure I shall be relieving the apprehensions of some of my audience if I begin by stating that I do not propose to inflict upon you a discourse on that threadbare theme. There are limits to the endurance even of those who practise a profession well calculated to inculcate the virtues of patience and forbearance.

When we have as president of the section one who has broken new paths in the exploration of the territory assigned to us, or to whose labours the fruitfulness of some corner of the domain may be chiefly attributed, we would hardly be disposed to tolerate the omission from his address of an account of his own special work, in investigation or in practice, and the developments to which it is leading. But while, no doubt, every worker is the chief authority on something or other, the plot he cultivates may be so restricted in area, and its products may bulk so little in the general harvest, as to form no suitable topic to engage the attention of his fellow-workers on such an occasion as this.

When an engineer leaves practice in the great, and takes to the devising and production of what are usually referred to specifically as "scientific instruments" (though all machines and mechanical appliances may properly be classed as such), his colleagues in the profession may be disposed to look upon the change as a degeneration of species. Naturally I am not disposed to accept such a verdict. Remembering the careers of those who did most in the founding of the various branches of present-day practice, I am quite prepared to accept as applicable another phase borrowed from the language of the biologist, and to let it be called a "reversion to a more primitive type." But instead of dealing with the narrow branch of applied science with which my own practice is chiefly connected, I prefer to utilise the short time at my disposal to make some observations upon a larger and more general theme. The thesis which I propose to uphold may not fall very obviously within the scope of the original aims of the British Association, but it has, at least, an intimate bearing on the work of those who are concerned with the applications of mechanical science.

Tredgold's oft-quoted definition of engineering as "the art of directing the great sources of power in nature for the use and convenience of man" may well be taken, and often has been taken, as a text upon which to hang a discourse on the importance of the profession to which many of us belong, the leading part it has played in the process of civilisation, and the dependence of the world to-day on its activities. But the words suggest failures as well as achievements, and responsibilities no less than privileges. The definition suggests that the engineer not only fails in his vocation if he does not accomplish something for the use and convenience of man, but further, that he acts contrary to the spirit of his profession if he directs the sources of power in Nature to the unuse* or inconvenience of man; and surely we must understand by "man" not the engineer's immediate client, but mankind in general. The works of the engineer are to be used by some people; they have to be endured by all.

Taking the highest view of our calling—and surely we do not hold that ours is in any sense a sordid or selfish vocation—the engineer fails in the fulfilment of his duty in so far as his works are detrimental to the health, or destructive to the property of the community, or in so far as they are unnecessarily offensive to any of the senses of those who are compelled to live with them. There has been too great a neglect of such considerations. The medical practitioner is held to be negligent of his duty if he acts solely in the immediate interests of his patient, and does not take due precaution to guard against the spread of disease or the offence of the community by the exhibition of unsightly forms. We should take as high a view of our responsibilities.

In his presidential address to the association last year, Sir Wm. Ramsay said that the question for the engineer has come to be not "can it be done?" but "will it pay to do it?" The answer to this question, in respect to any particular proposal, depends on the width of view we take in answering two preliminary questions, Whose interests are we to consider? and, What do we mean by paying? Of course, there are limits that must be set in answering each of these; my present contention is that these limits are usually much too narrowly drawn. A road surveyor may save a few pence or shillings to his county council by leaving a piece of newly metalled road unrolled—because the clock strikes the hour for retiring—and may thereby cause expense, amounting to pounds, it may be to hundreds of pounds, through damage to motor-cars or the laming of horses (not to speak of loss of life or limb), to the users of the road, who are, after all, the clientèle he is there to serve. Does it pay? The authorities of a city will spend large sums on the adornment of the streets with stately and ornate buildings, and on the purchase of works of art—and rightly so, though comparatively few of the citizens can appreciate or even give themselves the chance of appreciating them—while they will tolerate or even be directly responsible for the running on these same streets of quite unnecessarily ugly and noisy tramcars, and congratulate themselves on the drawing of a paltry income from the display of hideous advertisements that are constantly before the eyes of the whole community. Does it pay thus to separate æsthetic from utilitarian demands and interests?

It is too much to assume that engineers could meet all the reasonable demands of their immediate clients without producing, at least temporarily, secondary effects that may be of inconvenience to some members of the community. Bacon, indeed, said that "The introduction of new inventions seemeth to be the very chief of all human actions. Inventions make all men happy without either injury or damage to any one single person," but Bacon was a philosopher, and dealt with ideals rather than with hard facts, and in his times inventors had not yet begun to dominate all the elements of our physical environment. Had he lived to-day beside one of our country roads he might have had something to say, in another key, regarding motor-cars and dust; or had his lot been cast in the proximity of a great centre of industry he

* We have no word to denote very clearly the negative of *use*, as the term is here applied; *unuse* may serve it for the present.

might have modified his conviction of the universality of the benefits conferred by the inventor. He might even have been disposed to agree with a literary man of to-day who is reported as asserting that "The universal and blatant intrusion of science into our lives has resulted in a total disappearance of repose." Isolated and unqualified statements such as those I have quoted are like proverbs—you can always find two that are directly opposed. The truth lies about midway between these extremes, or rather there are aspects of the facts in regard to which one is an approach to the truth, and aspects in which the other has some justification. Our aim should be to make Bacon's dictum have more of truth and Mr. Stephen Coleridge's assertion have less foundation in fact. And the outlook seems to me to be a very hopeful one, though to be able to take an altogether favourable view of the tendencies of the present time, one must be an optimist of the true order—"One who can scent the harvest while the snow is on the ground."

When we examine into the immediate causes of the injuries and inconveniences that result from our activities we find that they are due in all, or almost all, cases to failures rather than to successes. The more completely the engineer achieves the primary end of his work the less is the damage or injury that can be laid to his charge. If it can be shown that this is a very general law, as I think it can be, we may look forward to the elimination, as a direct result of progress in the mechanical arts, of the nuisances and inconveniences for which, in some measure at least, we must accept responsibility. And not only so, but the converse will be equally true—the more we keep in view the removal or avoidance of anything that can cause offence, the more rapidly we shall advance in the attainment of the primary ends at which we aim. Consider, by way of example, the nuisance to which I have referred, and of which we hear so much—the raising of dust by motor-cars. I shall not discuss the debated question as to how far the motor-car produces dust, or only distributes it, nor shall I deal in detail with the possible remedies. We hope to have a paper on the subject at this meeting from one of our leading authorities. For my present purpose it suffices to point out that it is no part of the function of a road surface to fritter itself down into dust under traffic of any kind. The ideal road would be one that would not wear at all, and the nearer we approach this ideal of a permanent road surface the less will be the inconvenience caused, not only to those responsible for the upkeep of the road, but to the general public. And conversely, the more attention we give to the devising of a dustless road the more rapid will be our advance towards the provision of one best suited for all the purposes which a road is intended to serve. We had dusty roads before the motor-car came into being, but the demand that is being forced upon the engineer to eliminate this nuisance is leading to an improvement of our roads for all users. The inventors of the automobile will yet merit the thanks even of those who, bemoaning the blatant intrusion of science into our lives, may discard the railway train and the motor-car, and take to the stage-coach of their grandfathers with a view to the recovery of some of the lost repose.

Again, the combustion of fuel does little harm to anyone; it is the imperfection of the combustion that is the main cause, almost the sole cause, of injury to health, to property, and to the amenity of populous centres. Of course one knows that smokeless combustion is not necessarily, nor always, the most economical, but that is only because we have not yet learned how to use fuel in anything like a perfect manner. But all the tendencies at the present time are towards improvement, and the more attention we pay to the elimination of the smoke nuisance the more rapid will be our progress in the economical use of one of the most valuable of our inheritances. It is therefore clearly the duty of every engineer who has to do with power or heat production—for the credit of his profession, and even in the interests of his immediate clients—to consider the use and convenience of all who can be affected by the work for which he is responsible. The time is not far distant when the direct burning of bituminous coal in open grates will be looked upon as not only a source of serious harm, but as a culpably wasteful practice. Great progress has been made in processes for the partial distillation of coal by which a free burning and quite smokeless fuel is prepared, and valuable by-products (so-called) are conserved. If all engineers concerned with the design and application of plants in which coal is used had a due sense of their responsibilities to the community, progress would have been, and would to-day be, much more rapid; and economies would be effected that would, in themselves, amply justify the application of more scientific methods of utilising the constituents of a very complex material, which we are too apt to look upon as merely a convenient source of heat—plentiful enough and cheap enough, as yet, to be used in a most wasteful manner. It will not be to the credit of our profession if it should require restrictive legislation not only to prevent a gross interference with the health and comfort of the community and the amenities of our centres of industry or of population, but to effect economies in the utilisation of the chief of the sources of power which it is our function to direct to the best advantage of all concerned.

In other directions also we see that progress towards economy is leading to a reduction, and possibly to the entire elimination, of all the nuisances associated with the older methods of power and heat production. The great improvements that have recently been made in producer plants and gas engines have rendered out of date, as regards economy, at least the smaller sizes of steam plants which are so fruitful a source of injury and inconvenience to the community; and we now have engines of the Diesel, and the so-called semi-Diesel, types that can utilise natural oils, and oils obtained in the distillation or partial distillation of coal, not only with an efficiency hitherto unattained in heat engines, but "without injury or damage to any one single person"—except possibly the maker of inferior* plants.

Present indications point to the coming of a time, in the near future, when the power and heat required for industrial and domestic purposes will be distributed electrically, in a perfectly inoffensive manner, from large central stations; and even at these stations there will be no pollution of the atmosphere that could give the most sensitive of critics any just grounds of complaint against the intrusion of science into our lives. In his presidential address to the Institution of Electrical Engineers, in November, 1910, Mr. Ferranti dealt in a most masterly way with this, which is undoubtedly the greatest of the many schemes at present before the engineering profession. That address reads like a chapter from a romance of Utopia, but unlike most of the forecasts that have been presented to us of ideal conditions in a world of the future, the system which Mr. Ferranti sketches out, and advocates with so much knowledge and convincing argument, does not depend for its reasonableness on the postulation of a perfected humanity. It would not only provide vastly improved conditions of life for the community as a whole, but it would satisfy the more selfish aims of the users of power and the makers of machinery, by increasing the economy of production and stimulating the demand for mechanical appliances. No doubt there may be some who will hold that to commend any worthy scheme, to those who might carry it out, by an appeal to their selfish interests is an altogether immoral kind of argument. I do not think so. Advancement of the race through benefits to the individual is, at least, not inconsistent with nature's method of securing progress. However much we may desire to develop a purely altruistic spirit in men of all classes we must meantime make the best of human nature as it is, and recognise that the rapidity of our progress towards better conditions of life will be in proportion to the advantages that each advance can promise to those who would be immediately concerned in its realisation.

It is just a hundred years since passengers were first carried on the Clyde in a mechanically propelled ship, and to-day—when they are not too completely obscured by smoke—we can see the successors of the "Comet" plying on that river with power plants of greatly superior overall efficiency, but showing little advance in regard to the combustion of the fuel. Had the emission of smoke from river craft been prohibited years ago, there is little doubt that engineers would have let few days pass without arriving at some solution of the problem of inoffensive power production, and the

* My typist in describing a rather illegible draft of this passage substituted for the adjective I have here used the less restrained, but perhaps equally appropriate one, "infernal," but I noticed this in time to amend the emendation. I had no intention to speak so candidly of any of the works of members of my own profession.

demand for economy would have looked after itself. How much better it would be were engineers to take the wider view of their duties and responsibilities to which I have referred, and realise that they are acting contrary to the true spirit of their profession when they produce appliances that pollute the atmosphere for miles around to the hurt and inconvenience of those whose "use" they are intended to serve. But this year a ship has left the Clyde that we hope may be the forerunner of a new race which will attain a higher efficiency than any of the direct descendants of the "Comet," and that will ply their trade without inconvenience to man or beast, who can claim some right to be permitted to enjoy an unpolluted atmosphere and the measure of sunshine which Nature—sparingly enough in those regions—intended to provide.

But there are injuries which we may inflict upon the community other than those to health and physical comfort. Everyone, even the least cultured, has some sense of the beautiful and the comely, and is affected by the aspects of his environment more than he himself can realise. The engineer, then, whose works needlessly offend even the most fastidious taste is acting contrary to the spirit of his profession, at its best. There has been far too great a disregard of æsthetic considerations in the every-day work of the engineer—we usually take a too exclusively utilitarian view of our calling. We should not be prepared to accept, as referring to the arts we practise at their best, the distinction drawn by a philosophical writer between "the *mechanical* arts which can be efficiently exercised by mere trained habit, rote, or calculation," and "the fine arts which have to be exercised by a higher order of powers."* And I think it can be shown that a greater regard for artistic merit in our designs would not necessarily lead to extravagance, but, in many cases, would conduce to economy and efficiency. It is at least true—and much less than the whole truth—that greater artistic merit than is commonly found in our works could be attained with no sacrifice of structural fitness, or of suitability for the purposes they are designed to serve.

There was a time when engineers made desperate attempts to secure artistic effects by the embellishment (?) of their productions with features which they believed to be ornamental. Fortunately the standard of taste has risen above and beyond this practice in the case of most members of our profession and most of our clients. We are all familiar with illustrations of philosophical instruments, and other mechanical contrivances, of the early times, that vied in lavishness of adornment—though not in artistic merit—with those wonderful astronomical appliances that were carried—as trophies of war!—from Pekin to Sans Souci. Many of us can remember a time when the practice had not altogether disappeared, even in the design of steam engines, lathes, and other products of the mechanical engineer's workshop. I well remember in my apprenticeship days, the building of a beam engine that was a triumph of ingenuity in the misapplication of decorative features. In place of the mildly ornamented pillars and entablature of Watt's design, there was provided, for the support of the journals of the beam, a pair of A frames constructed in the form of elaborately moulded Gothic arches flanked by lesser arches on each side, while the beam itself and many other parts were plentifully provided with even less appropriate embellishments borrowed from the art of the stonemason. It is some consolation to remember that the clients for whom the engine was built were not of this country, and that the design itself was not a product of the workshop that was favoured with the contract to produce this amazing piece of cast-iron architecture. We have all seen wrought-iron bridges the unattractive features of which were concealed by cast-iron masks—in the form of panelling, or of sham pillars and arches with no visible means of support—that not only have no connection with the structural scheme, but suggest types of construction that could not, by any possibility, meet the requirements. Structures of this kind remind one of the pudding which the White Knight (with good reason, when we remember the characteristics of his genius) considered the cleverest of his many inventions. It began, he explained, with blotting-paper, and when Alice ventured to express the opinion that that would not be very nice, he assured her that though it might not be very nice *alone* she had no idea what a difference it made mixing it with other things—such as gunpowder and sealing-wax.

There are, and must always be, wide differences of opinion regarding what is good or bad in matters of taste, but we may go so far in generalisation as to say that we can admire the association of elements we *know* to be incongruous only in compositions that are intended to be humorous. "All human excellence has its basis in reason and propriety; and the mind, to be interested to any efficient purpose, must neither be distracted nor confused."† But to be able to judge of the propriety or reasonableness of any composition we must have some knowledge of the essential qualities and relationships of its component parts, and excellence cannot depend upon an appeal to ignorance. We can quite imagine that the White Knight's pudding would appeal as an admirable and most ingenious concoction to one who lacked a knowledge of the dietetic value of blotting-paper and was willing to take for granted the excellence of gunpowder as a spice and of sealing-wax as a flavouring. No artist would be bold enough to include a Polar bear or a walrus in the composition of a picture of the African desert, nor be prepared to consider as a legitimate exercise of the artistic imagination the depicting an Arab and his camel wending their weary way across the Arctic snows. He would recognise the incongruity, and might even realise that it is only a lack of imagination or of true inventive power that could lead anyone to resort to such measures for the securing of a desired colour scheme. These are lengths to which even artists will not go in the arrangement of elements in a composition. But an artist *will* secure a colour scheme at which he aims by the introduction into his landscape of a rainbow in an impossible position, or of impossible form or dimensions, or with colours arranged according to his own fancy, though in this there is a much more essential unreasonableness. A Polar bear might be transported to the desert, and an Arab might conceivably find his way to the regions of snow and ice, but a rainbow cannot wander from the place assigned to it by Nature, nor can it have other than the ordained form or dimensions or sequence of colours. No artist would paint a figure holding a candle and make the light fall on the side of the face remote from the source; but he will, and usually does, paint the moon illuminated on the side remote from the sun. Why? Simply because he has not before his mind the essential absurdity of the scheme, if indeed he knows why the moon shines. Artists who deal with nature in any of its aspects may be commended to "mark, learn, and inwardly digest" Whistler's definition of their calling: "Nature contains the elements in colour and form of all pictures . . . but the artist is born to pick and choose, and group with science, these elements, that the result may be beautiful." Whether or not we are to understand that Whistler intended to include an accurate knowledge of physical facts and phenomena in what he calls *science*, he cannot have meant anything less than *sense*.

So in regard to the arts of construction, we may say that mechanical science provides the elements of all structures, and the craftsman—be he called engineer or architect—is born to pick and choose, and group with science, these elements, that the result may be useful—and not devoid of grace.

The only valid excuse for such departures from the fit and rational in painting or in structural design as those which I have instanced is ignorance on the part of the designer of the nature of the elements he employs, or a lack of skill to devise a possible or reasonable arrangement of details that will secure the general effect he desires.

It may almost savour of sacrilege to quote, in this connection, from the writings of that "Wild, wilful, fancy's child" the story of whose eight short years of life and literary work Dr. John Brown has given in his charming "Pet Marjorie"—a record of perhaps the shortest human life that has formed the subject of a biography. But the lines are too pertinent to my purpose to be withheld, and the frankness

* "Enc. Brit.," eleventh edition, article "Art."

† Mr. Duppa's "Life of Michelangelo."

of the confessions they contain, of a childlike limitation of artistic power, may be commended to those who practise either the fine arts or the arts of construction, and feel compelled to "trust to their imagination for their facts," or to resort to the association of incompatible details for lack of knowledge, or of ability to attain their ends by more reasonable means.

Marjorie writes of the death of James II.:—

"He was killed by a common splinter,
Quite in the middle of the winter;
Perhaps it was not at that time,
But I could find no other rhyme!"

"Quite in the middle of the winter," describes August 3rd, 1460 A.D., with no wider license than we find assumed in the works of more experienced, if less candid, artists and craftsmen. Again, in her sonnet to a monkey—written, we must remember, when she was six or seven years of age—she acknowledges the compelling power of an artistic aim:—

"His nose's cast is of the Roman:
He is a very pretty woman.
I could not get a rhyme for Roman
So was obliged to call him woman."

It may seem that I have wandered widely from my text: those who found discourses on texts usually do! But there is, or ought to be, a closer connection than is usually recognised between the work of the engineer and that of those to whom we usually restrict the title of artist. There was no great gulf fixed between the fine arts and the utilitarian arts in earlier times. Some at least of those to whom we owe the greatest advances in the fine arts were eminent also in the arts of construction. We may claim such men as Michelangelo, Raphael, and Leonardo da Vinci as masters in the arts of construction as well as in those with which their names are usually associated. The separation of the beautiful and the useful is quite a modern vice. But much that I have ventured to say in the digression—if such it be—is applicable, with little or no alteration of terms, to the work of our own profession. The architect or engineer who, for the sake of effect, fills the space between the flanges of a beam or girder with slabs of stone, or cast-iron pillars and arches, that could not fulfil the function of a web, exhibits just the same lack of skill as Pet Marjorie owns up to—shall I say?—like a *man*. Such practices have no "basis in reason and propriety," and the employment of such "decorative features" is certainly not a "grouping of elements with science." It is said that "The highest art is to conceal art"; the lowest in matters pertaining to our profession is to conceal ill-devised construction with false and senseless masks. But what I have said has, I think, a sufficiently obvious bearing on the mechanical arts—I need not further point the moral.

There is an old maxim to the effect that "the designer should ornament his construction and not construct his ornament." This is an admirable rule so far as it goes, but it should be subordinated to a higher rule, that he should ornament his structure only if he lacks the skill to make it beautiful in itself. A structure of any kind that is intended to serve a useful end should have the beauty of appropriateness for the purpose it is to serve. It should tell the truth, and nothing but the truth, and if its character be such that it can be permitted to tell the whole truth, so much the better. It should be beautiful in the sense in which we commonly use the term with respect to a machine—we call a mechanical device beautiful only if it strikes us as accomplishing the end for which it is designed in the simplest and most direct way. Our works—like the highest creations in nature—should be beautiful and not beautified. "Beautified" should be considered a vile phrase when applied to a work of construction, no less than when used to characterise a fair Ophelia. Artists accept the human form, at its best, as the highest embodiment of grace and beauty, but there is not a curve in the figure that is not the contour of some structural detail that is there for a definite purpose. The practice of resorting to extraneous adornments to minimise crudities of structural scheme had its rise—if I mistake not—in the comparatively recent times when culture and taste were at their lowest. It is specially characteristic not only of earlier times, but of the earlier stages of the design of any particular product. It has already disappeared in some cases, and will continue to disappear from the practice of the arts of construction as skill and taste develop. I have already alluded to the abandonment of ornament in the design of machines, and I think there can be no one, with any sense of the fit and pleasing, who does not approve this change in practice. The stage coach and horses of former times were lavishly decorated—the carriage of to-day is more graceful and pleasing in virtue of the simple elegance of its lines. In the best domestic architecture of to-day we see the same tendency to trust for effect, more and more, to an artistic grouping of the lines and masses of essential parts and the gradual abandonment of purely decorative features, without and within. There was a time when the hulls and riggings and sails of ships were lavishly ornamented; now even the figurehead—the last remnant of barbaric taste—has disappeared; and do we not find in a full-rigged ship of to-day (or yesterday, perhaps one should say) a grace and dignity that no extraneous embellishments would enhance? From the racing yacht the designer has been forced, by the demand for efficiency, to cast off every weight and the adornments that so beset the craft of earlier times, with the result that there is left only a beautifully modelled hull, plain masts, and broad sweeps of canvas, and we can hardly imagine any more beautiful or graceful product of the constructive arts. These examples will serve to illustrate the contention that the attainment of the highest efficiency brings with it the greatest artistic merit. But in the development of the yacht of to-day, through many stages, the designer has been forced, from time to time, to strive to combine grace with efficiency. Selection on the part of clients must have eliminated ungraceful forms when more beautiful ones could be found, and therefore the advance has been rapid. I think I may appeal to this illustration to support the further contention that advance in efficiency may be helped and not hindered by keeping in view an æsthetic as well as a utilitarian aim. Further illustrations will occur to anyone who has studied the development of design of structures or machines.

It is a matter of constant remark, and with justice, that steel bridges, as a class, are much less pleasing to the eye than those of stone. The reasons for the contrast in artistic merit are not far to seek. The building of stone bridges is an ancient art, and survival of the fittest, and selection—even with little creative skill on the part of the designers—would have led to the development of types having, of necessity, at least the elegance of fitness. But further, this art has come down through the times to which I have referred when artistic and utilitarian aims had not yet been divorced, in the practice of the crafts; and further still, the practice of building in stone has been in the hands of architects, as well as of engineers, and architects are expected to be artists, and are trained as such. On the other hand, construction in steel is a very modern art, and it has been in the hands of engineers who usually neglect, if they do not despise, the study of the fine arts. But why have architects, with their artistic training, not succeeded in producing structures in steel as admirably as those they design in stone? Partly, no doubt, because they are hampered by tradition. They have not yet fully realised the difference in spirit that must characterise fit designs in the newer and the older materials. No one can be an artist in any material, the possibilities and limitations of which he has not fully mastered. Again—if a common engineer may venture the criticism—the architect, as a rule, has not sufficiently mastered the *science* of construction, and has been too much addicted to taking the easy course of adopting a decorated treatment instead of striving to secure elegance of structural scheme as such; and decoration, at least on anything like traditional lines, is wholly incompatible with the best possibilities of steel as a structural material. Progress is being made in the art of designing efficient and graceful structures in metal, but the best results can only be attained by a designer who has a thorough scientific and technical knowledge of the properties of steel and the processes of its manipulation, on the one hand, and cultured artistic sense and capacity on the other. These should not be considered as appropriate equipments for separate professions.

There are many, however, who have a rooted conviction that structures in steel can never be so beautiful as those in stone. This I believe to be altogether wrong. It arises partly from the crudity of design that characterises most of the steel structures that have yet been erected, and partly from preconceived notions as to what is fitting in proportions and massiveness. We can quite imagine that a native of the Congo region whose notions of the proportions suitable and comely for a quadruped were founded on his familiarity with the hippopotamus would, at first sight, consider the racehorse sadly lacking in substance and solidity, but, in time, he might come to recognise some measure of gracefulness in a creature that has been developed to meet requirements that hitherto he had not fully considered.

Mr. Wells has said in his "New Utopia," "the world still does not dream of the things that will be done with thought and steel when the engineer is sufficiently educated to be an artist, and the artistic intelligence has been quickened to the accomplishment of an engineer." But we need not postpone, till the advent of a complete Utopia, the full realisation of our duty to practise our profession as far as in us lies, with due regard for the material interests and the æsthetic susceptibilities of all who can be affected by the works for which we are responsible.

THE INSPECTION OF LOCOMOTIVE BOILERS.

In a recent issue of the "Santa Fe Employés' Magazine," Mr. George Austin, general boiler inspector of the Atchison, Topeka, and Santa Fe Railway, contributes an article dealing with the work of the locomotive boiler inspector. No part of the locomotive boiler or firebox will, he states, wear out more quickly than another part if it receives equally as good treatment. For a firebox sheet to crack or bulge it must previously have been over-heated. The same treatment applies to flues or seams, and the boiler inspector, having found such a condition, should look for the cause. The evidence of rapid degeneration of a firebox sheet usually is pretty clearly shown on the fire side, usually by leaky stay bolts, a slight cracking in the stay-bolt holes, or a slight bulging of the sheets between the stay bolts. This very frequently is the case with door sheets. Sometimes it is found in the crown sheet or in the side sheets, and in almost every case investigation shows that it is caused by over-heating, and is due to one of two things—either to scale and mud forming on the water sides or to improper draughting, either at the smokebox end or the back end, or both. It is rarely found that all the parts of a locomotive firebox show equal evidence of wear, over-heating, or rapid deterioration. Usually there are one or more parts that show up worse than the others, and there is a cause for this, and that is what the boiler inspector should find out.

The boiler inspector prides himself on his ability to detect broken or defective stay bolts, but such work is only a part of his duties. A great deal of trouble is due to poor boiler washing, scale being allowed to accumulate around stay bolts and on the plates until it has become so heavy as to keep the water away from the metal, causing over-heating. Even with the best water there is a continuous formation of scale, some of which is very dense, and a comparatively thin layer, not one-sixteenth of an inch thick, is liable to cause over-heating under conditions which may concentrate the flame at any one point. This is sometimes caused by a banked fire, at other times by a dirty fire, and again it may be caused by improper draughting.

Take the case of firedoor sheets that show unusual stay-bolt leakage or bulging between bolts. Investigation often discloses the fact that the deflecting sheet was run too high, that an excess of overdraught was produced, and that too much of the fuel was being consumed at the back part of the firebox. At other times it would be shown that scale or mud was forming. In the case of some engines giving unusual trouble from leaky flues, investigation would probably show there was not sufficient overdraught. It is not presumed to give a definite statement as to just what is the cause of the unequal draughting, but conditions often point out that there is something wrong with it, and it should be the care of the boiler inspector at least to report that condition and have it investigated. The boiler inspector should realise that it is his particular duty to prevent the necessity for repairs, which can be done only by observing carefully the condition of any firebox he inspects, looking particularly for unusual developments. It does not enlighten one to say that a cracked side sheet or door sheet is due to contraction or expansion. Everyone knows that. What is desirable to know is the cause in a particular case of expansion or contraction, and if the inspector can tell, he also very likely knows what to do to prevent it.

A locomotive may be a good steamer, may be economical in fuel—may be entirely satisfactory in that respect—and yet may not be properly draughted (*i.e.*, from the standpoint of equal distribution of heat), and it is this unequal distribution of heat in the firebox, in connection with the deposit of scale or mud, that develops defects in one part of the firebox more than in another, whether it be side sheets, door sheet, crown sheet, or flue sheet, and, when we consider the fact that the hotter a firebox sheet is the greater the evaporation, and consequently the greater the incrustation at that hot point, due to the greater evaporation, it is not difficult to understand why over-heating occurs when heat is not evenly distributed in a firebox.

It is to conditions of this kind that the attention of locomotive boiler inspectors is especially invited. They should be continually on the alert to detect such conditions, and should strive to improve them. In an average roundhouse there never is a time when there is not some problem that should be calling for the exercise of his judgment and ability. In the inspection of the interior of the boiler he should be thorough and painstaking, always on the look out for defects. Superficial inspection is of little value; he must examine closely. He must look for cracked side sheets, broken brace pins and missing cotters, and must see that the water spaces are clean and free from scale. He must be particularly careful to examine along mud rings and to remove all rivets, bolts, and tools that may have fallen. He must see that the scale is scraped away from all parts of the interior, so that there is no possibility of any defect being hidden. He should interest himself in the condition of the flues, to see that they are properly cleaned, and that the beads are properly set up. He should know the air spaces in the grate bars are free from cinders, and that external corrosion is not taking place behind the side bars.

He should be thoroughly in touch with the ashpan and grates, noting that the grates operate freely and with a full opening without excessive lost motion; that the ashpans are tight, and that the slides operate freely and close properly to avoid the probability of dropping fire. He should examine the brick arch tubes, and should know whether any roughness is apparent on the outside, which condition denotes the formation of scale on the inside. He should inspect thoroughly the front end appliances, and should know that they are secured properly to prevent the throwing of fires. He should know that the front end and the hoppers and plates are tight and do not admit air to the smoke arch. When the boilers are being washed he should inspect the interior carefully, and should see that they are being cleaned properly.

It is the constant practice of his profession in inspecting these parts that develops in him the ability to quickly comprehend the condition of a boiler or firebox, and his expertness and reliability along these lines give him a standing with his superiors that can be acquired only by the thoroughly competent man. He will find that his efforts will be rewarded to the extent that he will be accepted as an authority, and if his immediate superior or anyone else interested wants to know the condition of a firebox or boiler he will feel satisfied that the decision of that particular boiler inspector is as good as anyone can give, and it is very gratifying to one to have established for himself a standing of this kind.

Liner's Coaling Record.—Some 4,000 tons of coal was put into the bunkers of the White Star liner "Olympic" in $14\frac{1}{4}$ hours at Southampton on the 29th ult. This is a record for the port, and is believed to be a world's record. Thirty-two gangs of men were employed, or 10 more than usual. An average rate of 288 tons an hour was maintained throughout the night.

CONDENSERS AND CONDENSATION FOR VACUUM PLANTS.

BY B. VIOLA.

THE condensation of vapours may be carried out in two different ways—viz., by dry surface-condensation or by wet injection-condensation, according to whether the vapour comes in contact with the cooling water only indirectly by means of a dry cooling surface or directly without intervening plates.

Dry condensation is commonly employed in steam engine plants in order to keep the feed water free from impurities or salts; wet condensation is generally used where cold water (seldom cold air) may be directly injected into the condenser without disadvantage.

Another distinction is made between direct-current and counter-current condensers, according to whether the cooling water and the steam or vapour move in the same or opposite directions. In either case the steam or vapour is deprived of the latent heat by which it was produced, and it is precipitated once more as water in the form of drops, while simultaneously the pressure exerted by the steam disappears and a vacuum is produced.

Wet condensation is the kind chiefly used in vacuum plants. The cooling surface here is the surface of the cooling liquid while flowing off. The steam, being brought into contact with this cooling surface, will condense, reducing its volume and pressure. According to the ability of the cooling water to consume heat, a certain quantity of steam can be condensed continuously per unit of time and surface.

If a vacuum pan is connected with a condenser, the reduction of pressure in the condenser will communicate itself to the steam space, in consequence of the tendency toward equalisation of pressures in communicating rooms, and the difference of pressure between boiling surface and condensation surface will be only the amount of pressure required for overcoming the resistance of friction of steam and gases during their motion. These resistances are very different, according to the construction of the condensers and the shape and dimensions of the connecting pipes.

In order to maintain a constant pressure in the vacuum pan, it is not merely sufficient to condense the vapours. With the cooling water a vast amount of atmospheric air and carbonic acid is introduced continuously into the apparatus. Besides, the alkaline earths dissolved in the water can produce gases which will become noticeable at higher temperatures. Even in the evaporator gases, carbonic acid, &c., are produced. All the gases set free from the cooling water have a motion opposite to that of the steam; they penetrate the latter, mix with the gases coming from the evaporator, and alter their own motion only in the upper part of the condenser, or at the air-pump connection.

If the gases were not allowed to escape from the condenser they would soon fill the room of the vacuum pan to such an extent that in spite of good condensation the pressure would be considerably increased. They would also follow the pitch to the cooling surface, taking up the volume formerly occupied by the condensed steam, would delay the cooling of the steam, and finally stop condensation altogether. To avoid this, an air pump is attached to the upper part of every counter-current condenser in order to take care of these gases.

The cooling water gives off the absorbed air upon entering the condenser in the same proportion as the pressure is reduced. The air is therefore carried off by the air pump from the upper part of the condenser at the lowest temperature, never reaching the lower part of the condenser, and only promoting the condensation of the vapours in the upper part. It is generally known that 0·07 is the proportion of air in the water in a wet condenser, including that passing through leaky joints. We therefore see how important it is never to inject any more water than the vapours require for their condensation.

In practice it is very often found that by an incorrect working of the vacuum, or of the condensing plant the injection of cooling water is increased. Such a faulty operation is indicated by various symptoms, but most strikingly by the temperature of the condensed water. If the flow of cooling water is too rapid, the work of the air pump is immediately made more difficult, since a great deal more air is to be removed. If the air pump is accurately proportioned according to the size of the plant, it will now be unable to accomplish the work. If it is larger, the work is done at the expense of more steam. If a wet-air pump is employed it is called upon to remove more air and water. Moreover, the excessive injection of water will cause a higher pressure in the condenser.

Suppose the falling water to be a liquid cylinder, the outer surface or mantle of this cylinder will, upon entering into the hot steam, first take up the heat of the steam, while the interior parts remain cooler. If, owing to the great velocity of fall, the interior portions of the water column are unable to effect cooling as well as the exterior surface, the discharged water will be heated only to a moderate degree. But if an equalisation of temperature can be brought about through the whole cylinder of water, while it is falling, the cooling power of the water is utilised to much better effect.

The finer the water can be subdivided in falling, the more readily will the gases pass through it, and their resistance will be diminished as the surface increases. The subdivision of the water brings about largely the escape of the air from the cooling water. But the division is never fine enough; hence in counter-current condensers the real counter-flow takes place only upon the surface where the water and steam are in contact. But the utilisation of the cooling surface also depends on the time of contact—that is, on the time for which there is a maximum temperature difference between water and steam. For the free fall of a body of water the time of falling t is equal to the velocity v, divided by the gravity g, or $t = v/g$. The height of the fall h expressed by the velocity is found from

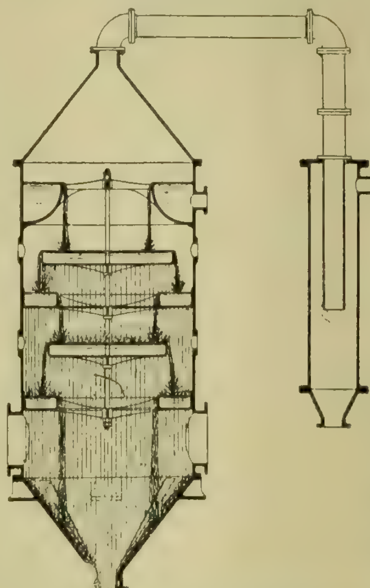


FIG. 1.—COUNTER-CURRENT CONDENSER.

$$v = 2\sqrt{gh} \text{ or } t_h = \frac{\sqrt{2gh}}{g} = \sqrt{\frac{2}{g}} \times \sqrt{h}.$$

Applying this equation to condensation, we may say that the time t_h required for a fall from the height h increases proportionately to the square root of the height of the fall. But with the height of fall the resistance in the condenser also increases. We can divide the height of fall into n parts (for instance, by providing a series of basins or trays as will be described later on), and thus have:—

$$h = n \times h/n.$$

The partial fall being h/n, and giving to the resistances the smallest value possible, and to the time of transferring heat in the condenser the highest value, we call the limit of the time of contact of water and heat $t_{(nh,n)}$, and have this equation:—

$$t_{(nh,n)} = \sqrt{2nh/g}$$

From this we derive the proportion:—

$$\frac{t_h}{t_{(nh,n)}} = \frac{1}{\sqrt{n}}.$$

Then for every value of $n > 1$ we shall also have—

$$t_{(nh,n)} > t_h, \text{ and in general } t_{(nh,n)} = \sqrt{n}\, t_h.$$

If we make n very large and h/n very small, we shall proportionately extend the time of contact between steam and water in the condenser.

$$\frac{h}{n} = \frac{gt^2}{2n^2}.$$

It is necessary, however, that the partial fall h/n be not less than the value required by the amount of steam to be condensed.

From this calculation we see that the velocity of the water is governed by the height of fall, and it is advisable to restrict this height in order to prevent friction resistance, if for no other reason. The smallest value of friction resistance corre-

sponds to $h = o$; that is, the condition when steam and gases flow over standing water. Plants of such construction, however, would be too large. Moreover, water and gases being poor heat conductors when in a state of rest, it is necessary to provide for a certain degree of motion for the water in a condenser. Further, the quantity of steam condensed per unit of time is directly proportional to the cooling surface, and a division of the cooling water is therefore equivalent to an extension of the cooling surface.

Therefore, to heat the condenser water quickly to the necessary temperature by direct contact with steam it is necessary—(1) That the surface of the cooling water be large; (2) that the cooling surface change quickly; and (3) that the time of contact between steam and water be as long as possible.

To fulfil these conditions a concentric counter-current condenser such as that shown in Fig. 1 gives the best results. This condenser is designed for use in connection with two or more vacuum pans. By the addition of basins or trays the duration of the contact between water and steam is raised in the ratio of $\sqrt{n}$, resulting in an economy of water. Some water will accumulate in each of these trays temporarily, and the temperature is therefore equalised at each stage. The fresh supply of water will sink to the bottom of the tray, forcing the lower stratum upward on account of the difference in temperature, and the warmer water will flow over from one tray to the next. The trays in this manner form zones with the desired small difference of temperature, and constitute a graduated scale of temperatures from the temperature of the steam admission to that of the gas outlet.

The surface of condensation depends primarily on the size of the cooling-water cylinder when the depth of the trays is greater than zero. It may even be said that these moving water columns promote the cooling, and air and gases will pass at the surface of the trays even though they do not pass at the bottom. During the time the water remains in the trays it has a chance to take up more heat which is withdrawn from the steam. It is very important that enough water be permitted to flow to secure good results, but by providing the trays with spray holes the cooling effect of the water is considerably increased.

The work of the condenser varies with temperature, but in general it performs about 610 times the work of the air pump, volumetrically speaking. It is absolutely necessary to exhaust the air and gases to promote condensation, but the best air pump cannot do good work with a poor condenser, while a good condenser accomplishes at least fair results with an indifferent air pump.

As I have explained, it is very important that the correct quantity of water be used to condense a certain quantity of steam. This matter is neglected in most condensing plants, and some kind of automatic device should be applied to regulate the flow of cooling water. Experience has shown that the amount of water should be from 20 to 40 times that of the steam to be condensed. This permits variations within very wide limits, and in large condensing plants where immense quantities of cooling water are required, some controlling device should be applied for economical reasons to prevent waste of water.—"Metallurgical and Chemical Engineering."

Trailing Tramcars.—Some interesting figures have been gathered by Mr. A. L. C. Fell, chief tramway officer of the London County Council, regarding the extent to which trailing tramcars are employed in various cities. These show that 1,419 are used in Vienna, 1,246 in Berlin, 702 in Paris, 651 in Hamburg, 445 in Marseilles, 350 in Cologne, 241 in Milan, 240 in Amsterdam, 216 in Copenhagen, 170 in Pittsburg, 168 in Toronto, 110 in Bordeaux, and 74 in Sydney—a total for the 13 cities of 6,032. The greatest number of such cars hauled by one motor tramcar is three, in Brussels and Marseilles. The greatest length of the trains is 196·8ft., on the Cologne Bonner line, followed by 132ft. in Sydney, 124·3ft. in Paris, and 102·3ft. in Vienna. The greatest speed attained is 21·75 m.p.h., in Marseilles and Milan, followed by 20 m.p.h. in Sydney, 18·6 m.p.h. in Vienna and Hamburg, and by 18 m.p.h. in Amsterdam. In regard to speed the lowest position is taken by Bordeaux with 12·4 m.p.h.

ELECTRICAL NOMENCLATURE.

(Concluded from page 272.)

Master Controller or Pilot Controller.—A controller used in the multiple unit system of electrification. It does not act directly on the current supplied to the motors, but works electromagnetic or other switches called contactors. These contactors control the motors.

Maximum-demand System.—A system for assessing the payment to be made for a supply of electrical energy composed of two parts: (1) A sum depending on the maximum power supplied during a certain period; and (2) a sum proportional to the energy supplied during that period.

Meg-, Mega-.—A prefix signifying one million times, *e.g.*, megohm, one million ohms; megavolt, one million volts.

Messenger.—A name used in America for a wire or cable from which electric wires or cables are hung. Called in railway work a catenary, in telephone and telegraph work a suspending wire.

Mho.—The unit of conductance. The reciprocal of the ohm. The conductance of a circuit the resistance of which is 1 ohm.

Micro-.—A prefix signifying one-millionth part, *e.g.*, micro-ampere, one-millionth of an ampere; microfarad, one-millionth of a farad.

Micron.—One-millionth of a metre, *i.e.*, one-thousandth of a millimetre.

Microphone.—A device employed at the transmitting end of a telephone circuit, consisting of a contact or system of contacts such that the resistance is altered by the impact of the sound waves.

Middle Wire.—The conductor of a three-wire system of supply, the potential of which is intermediate between those of the other two. Sometimes called the intermediate or neutral.

Mil.—One-thousandth of an inch.

Mil or Circular.—A unit used in America, the area of a circle of which the diameter is one-thousandth of an inch.

Milli-.—A prefix signifying one-thousandth part, *e.g.*, milliampere, one-thousandth of an ampere.

Milker.—A dynamo used for charging individual cells forming a portion of a battery of accumulators. Sometimes called milking booster.

Mirror Galvanometer.—A galvanometer having a mirror attached to the moving part. A beam of light reflected from the mirror is used as a pointer, or the image of a scale is observed in the mirror by means of a telescope.

Moment.—(*a*) Of a force. The effectiveness of a force to produce rotation about a point. The product of the magnitude of the force and the length of the perpendicular let fall on its line of action from the point. (*b*) Of a couple. The product of the magnitude of one of the two equal forces and the arm or perpendicular distance between them. (*c*) Of a magnet. The product of the strength of one of the poles of a magnet and the distance between them.

Morse Alphabet.—A signalling code in which two different signals arranged in groups of one or more are used to represent a letter, figure, or symbol.

Motor.—A machine for converting electrical energy into mechanical energy.

Motor Generator.—A machine consisting of a dynamo or alternator driven by an electric motor, either in the form of two distinct parts coupled together, or having the armature windings on a common core and revolving in a common field. Sometimes called a dynamotor, a term not recommended.

Motor Transformer.—A term not recommended. (*See* Transformer.)

Mouse Mill.—A special continuous-current motor used for running paper strip through a syphon recorder.

Moving Coil Instrument.—A measuring instrument, the indication of which depends on the torque exerted by a magnetic field on a coil through which the current to be measured passes.

Multicellular Voltmeter or Electrometer.—An instrument in which several pairs of quadrants act on several needles mounted on one axis.

Multiphase.—Synonym for polyphase.

Multiple Arc.—Synonym for connection in parallel. A term not recommended.

Multiple Board.—A form of telephone switchboard.

Multiple Unit System.—A system of electric traction in which two or more cars are units in themselves and have their own motors controlled by electromagnetic or other switches called contactors. When the cars are coupled together as a train the contactors can all be worked from a single master controller.

Multiplex Telegraphy.—A telegraphic system in which several messages, generally more than two in either direction, can be transmitted on one circuit at the same time.

Multipolar Generator or Motor.—A dynamo, alternator, or motor having more than one pair of magnetic poles.

Mutual Induction.—(*See* Induction, Mutual.)

Needle.—A name originally applied to the moving magnet of a mariner's compass, later to the similar magnet of a galvanometer, and to the paddle-shaped moving conductor of a quadrant electrometer.

Needle Astatic.—(*See* Astatic.)

Negative.—Of the two poles of any source of electricity that one is called negative which corresponds, as far as the direction of the current in the external circuit is concerned, to the zinc plate of a Daniell cell.

Network.—A number of conductors inter-connected for the distribution of electrical energy in a supply system.

Neutral.—(*a*) In a three-wire system of supply, the middle wire is sometimes called the neutral, or intermediate. (*b*) The point of junction of the conductor of a star connected polyphase system of alternate-current working. (*See* Phase.) (*c*) Points on a dynamo commutator. Those points between which there is a maximum electromotive force when the dynamo is running on open circuit.

Nominal Horse-power.—An obsolete mode of describing the output of a steam engine in terms of certain of its dimensions.

Non-inductive.—(*a*) Circuit: A circuit so arranged that its self-induction is practically negligible. (*b*) Winding: Two identical insulated conductors laid side by side or twisted together and so connected that a current traversing them in opposite directions generates no sensible magnetic field. (*c*) Load: A load such that its self-induction is practically negligible.

Ohm.—(*a*) True: The unit of resistance in the practical system of units. The value in the C.G.S. system is equal to 10^9 electromagnetic units. (*b*) International: The resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14·4521 grammes in mass, of a constant cross-sectional area and of a length of 106·300 centimetres. (International Conference, 1908, and British Order in Council, January 10th, 1910.)

Ohmmeter.—An instrument for measuring electrical resistance by the deflection of a pointer over a scale.

Oil Transformer. A transformer immersed in oil.

Omnibus Bar.—(*See* 'Bus Bar.)

Oscillation, Electric.—When a system or circuit possessing capacity and self-induction is disturbed from its condition of electrical equilibrium, the currents flowing alternately in opposite directions with decreasing amplitude during the return to equilibrium are called electric oscillations.

Oscillating Circuit.—A circuit in which electrical oscillations can freely take place.

Oscillator.—A conductor having effectively both self-induction and capacity in which electric oscillations can be set up.

Oscillograph.—An apparatus for observing or recording quickly varying currents or potential differences.

Outer.—The two conductors of a three-wire system between which there is a maximum voltage are called the outers. A term not recommended as a synonym for the external conductor of a concentric cable.

Output.—A synonym for load. The total power delivered at the shaft or at the terminals of a machine or apparatus. (*See* Rated Output.)

Over Compounding.—(*a*) Of a generator: A generator is said to be over compounded when the potential difference between its terminals increases with the load. (*b*) Of a motor: A motor is said to be over compounded when the speed increases with the load.

Over-load.—A load greater than the rated load.

Over-load Circuit Breaker.—An automatic switch which opens when a pre-determined load is exceeded.

Parallel.—(*a*) Two or more systems of conductors are said to be in parallel in a circuit when the current flowing in the circuit is divided between the two systems. (*b*) Two or more systems of conductors, generators, or motors are said to be connected in parallel when the terminals of the same sign are electrically connected together.

Paramagnetic.—A substance of which the magnetic permeability is greater than unity (vacuum).

Paste (*of an Accumulator*).—The active material of the plates or grids of an accumulator. So called as it is sometimes applied as a moist composition or paste.

Peltier Effect.—The liberation or absorption of heat which takes place in a heterogeneous circuit at the joint where an electric current passes from one material to another.

Period (*Periodic Time*).—Any varying quantity which repeats its values regularly at equal time intervals is said to be periodic, and the time interval of one repetition is called the periodic time or period.

Permanent Magnet.—A body which, having been magnetised, retains a substantial portion of its magnetism.

Permeability.—(*See* Magnetic Permeability.)

Permeance.—(*See* Magnetic Permeance.)

Phase.—(*a*) In an operation which occurs harmonically, the stage or state to which the operation has proceeded. (*b*) In an operation which recurs harmonically, the fraction of the whole period which has elapsed, measured from some fixed origin. (*c*) *Phase Difference*: The difference of phase (usually reckoned in time or in angle) between two periodic quantities which vary harmonically and have the same frequency. (*See* Lag.) (*d*) Each of the circuits of a polyphase apparatus is sometimes called a phase. *Single Phase*: A supply is said to be single phase when it consists of a single alternating current. *Two Phase*: A supply is said to be two phase when it consists of two alternating currents which are displaced with regard to one another by one-quarter of a period. *Three Phase*: A supply said to be three-phase when it consists of three alternating currents displaced with regard to one another by one-third of a period. *Polyphase*: A supply is said to be polyphase when it consists of more than one alternating current displaced with regard to one another by equal periods.

Phase Angle.—The angle between two vectors representing two simple harmonic periodic quantities having the same frequency but differing in phase from one another, *e.g.*, the vectors representing alternating voltage and the current produced by it. Extended Meaning.—The angle between any two vectors which represent quantities having the same fundamental frequency.

Phasemeter.—Apparatus for measuring the distance of phase between two periodic electric quantities of the same frequency.

Photo-electric Effects.—Any changes in the electrical properties of a body produced by the action of light, *e.g.*, generation of electromotive force, change of resistance, or loss of charge.

Piezo-electric Effect.—The production of electrification by mechanical pressure.

Pile.—(*a*) Thermo-electric: A source of electrical energy due to the direct transformation of heat into electrical energy, generally consisting of a series of thermo-junctions. (*b*) Voltaic: An obsolete synonym for a battery of cells.

Pilot Wire.—(*a*) A wire used for measuring the voltage at a distant part of a network. (*b*) In a multiple-unit system, a wire used between the master controller and a contactor.

Plant.—A collective term, including various machines, equipment, and apparatus used together for any purpose.

Planté Plates.—Accumulator plates prepared by electrolytic action on lead in acid. (Process invented by G. Planté.)

Plough.—An appliance for effecting a sliding electrical connection between the conductors of a conduit system and the electric equipment of a car.

Plug Contact.—A slightly conical or screwed metal plug for making electrical contact between two conductors, conducting bars or blocks, or between the bars or blocks and the plug.

Point (in Wiring).—The termination of the wiring for attachment to the fitting for one or more lamps or other consuming devices.

Polarisation.—A condition set up in a battery or electrolytic cell as a result of the passage of a current, and which manifests itself by a back-electromotive force.

Polarity.—A quality of a body in virtue of which certain characteristic properties are manifested at points called poles.

Pole.—(*a*) Of a Cell: Synonym for the terminal or the accessible part of an electrode. (*b*) Of a Magnet: Points towards which lines of force converge, or at which the resultant magnetic force may be considered to act. (*c*) Of an Arc: The extremity of each of the electrodes between which the arc burns.

Pole-piece.—Any specially shaped piece of magnetic material forming a polar extension, and, in the case of a generator or motor, facing the armature.

Polyphase.—(*See* Phase.)

Positive.—Of the two poles of any source of electricity, that one is called positive which corresponds, as far as the direction of the current in the external circuit is concerned, to the copper plate of a Daniell cell.

Potential, Difference of.—(*a*) Electric: A difference of potential exists between any two points if energy is expended or acquired in moving a unit of electricity from one point to the other. In practice measured by a voltmeter. (*b*) Magnetic: A difference of potential exists between any two points if energy is expended or acquired in moving a unit magnetic pole from one point to the other.

Potentiometer.—An instrument for measuring electrical quantities depending in principle on balancing an unknown difference of potential against a known fall of potential obtained by the passage of a current through an adjustable resistance.

Power.—The rate of doing work. Units: the watt, kilowatt, and horse-power.

Power Factor.—The ratio of the watts to the volt-amperes.

Practical Units.—Some of the units of the centimetre-gramme-second or C.G.S. system are inconveniently large or small for practical purposes, and therefore certain practical units have been chosen which are made some decimal multiple or sub-multiple of the corresponding units. Thus, the ampere is one-tenth and the volt is one hundred million times the C.G.S. unit (electromagnetic) of current and the C.G.S. unit of electromotive force respectively.

Pressure.—Often used as a synonym for voltage, electromotive force, difference of potential.

Primary.—(*a*) Cell or Battery. (*See* Cell, in contradistinction to a secondary battery or an accumulator.) (*b*) Of a Transformer: That winding of a transformer to which electrical energy is supplied.

Pull-off.—(*See* Ear.)

Pulsating Current or Pulsatory Current.—A unidirectional current which varies in some periodic or quasi-periodic manner.

Pyro-electric Effect.—The electrostatic charge produced by heating a body (particularly the substance tourmaline).

Pyrometer.—An instrument for measuring temperatures higher than those measurable by an ordinary thermometer.

Quadrant Electrometer.—A measuring instrument consisting of a moving vane or needle placed within or near four quadrants, the electrostatic forces between the fixed quadrants and the moving needle producing the deflection.

Quadruplex Telegraphy.—The method in telegraphy in which four messages are sent simultaneously, two in each direction.

Quantity.—(*a*) Of Electricity: The product of current into time. Units, coulomb, and ampere-hour. (*b*) Obsolete term for the strength of a current, as distinguished from the intensity of the battery which furnishes the current.

BOILER ECONOMICS AND THE USE OF HIGH GAS SPEEDS.*

BY J. T. NICOLSON.

(*Continued from page 263.*)

The Fan.—The question of the fan must now be taken up in order to find the work to be spent upon it, and the steam required to do that work. The number of foot-pounds needed to compress 1lb. of air (or chimney gas) of absolute temperature τ, from a pressure P, pounds square foot, to a higher pressure, P_0 (that of the atmosphere) is

$$W_1 = 53{\cdot}2\tau \log_e \frac{P_0}{P} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

or

$$W_2 = 3{\cdot}5 \times 53{\cdot}2\tau \left[\left(\frac{P_0}{P} \right)^{\frac{1}{3\cdot5}} - 1 \right] \quad . \quad . \quad . \quad (16)$$

or

$$W_3 = 53{\cdot}2\tau \left[\frac{P_0}{P} - 1 \right] \quad . \quad . \quad . \quad . \quad . \quad (17)$$

according as the compression takes place isothermally, adiabatically, or at constant volume.

For small pressure differences it is found that the three expressions give results which are very nearly the same. Thus with $P_0 = 144 \times 14{\cdot}7$, $P = 144 \times 13{\cdot}7$, and $\tau = 212 + 461 = 673°$ Fah.,

$$W_1 = 35{,}750 \times 0{\cdot}07045 = 2{,}520 \text{ ft.-lbs.}$$
$$W_2 = 35{,}750 \times 3{\cdot}5 \times 0{\cdot}021 = 2{,}610 \text{ ft.-lbs.}$$
$$\text{and } W_3 = 35{,}750 \times 0{\cdot}073 = 2{,}610 \text{ ft.-lbs.}$$

Thus it may be assumed that the net work to compress 1lb. of air at 212° Fah. from 13·7 to 14·7lbs. per square inch is 2,600 ft.-lbs. One pound per square inch is equivalent to 27·7in. of water gauge; therefore, to compress 1lb. of such air through 1in. of water gauge takes about $\frac{2{,}600}{27{\cdot}7} = 94$ ft.-lbs. net.

To compress the gases produced by (F) the number of pounds of coal burnt per hour on one square foot of grate through $\triangle P$ inches of water gauge will require $94\,(A + 1)\, F \triangle P$ foot-pounds (net) of work per hour, or

with $A + 1 = \frac{300}{F} + 10$, it will require

$$\frac{94(300 + 10F)}{1{,}980{,}000} \triangle P \text{ horse-power (net).}$$

Allowing a fan efficiency of 70 per cent., the work required will be $\frac{94}{0{\cdot}7} = 135$ ft.-lbs. per pound, and the horse-power required is $\frac{135(300 + 10F)}{1{,}980{,}000} \triangle P$ shaft horse-power.

TABLE IX.—*Shaft Horse-power and Steam per Hour for the Fan per Square Foot of Grate.*

F	10	20	30	40	5[illegible]	60	100
300 + 10F	400	500	600	700	800	900	1,300
S.H.P.	$\frac{\triangle P}{36{\cdot}7}$	$\frac{\triangle P}{29{\cdot}4}$	$\frac{\triangle P}{24{\cdot}5}$	$\frac{\triangle P}{21}$	$\frac{\triangle P}{18{\cdot}3}$	$\frac{\triangle P}{16{\cdot}3}$	$\frac{\triangle P}{11{\cdot}3}$
Steam per hour per square foot of grate	$0{\cdot}68\triangle P$	$0{\cdot}85\triangle P$	$\triangle P$	$1{\cdot}19\triangle P$	$1{\cdot}37\triangle P$	$1{\cdot}53\triangle P$	$2{\cdot}2\triangle P$

Allowing 25lbs. of steam per shaft horse-power hour, the steam needed to drive the fan per square foot of grate will be:—

$$\frac{25 \times 135(300 + 10F)}{1{,}980{,}000} \triangle P \text{ pounds per hour} \quad . \quad . \quad . \quad (18)$$

Thus the annexed Table IX. is obtained.

The value of $(\triangle P'')$ the draught, in inches of water, in terms of the gas temperature and pressure, the mass-flow, and the surface-section ratio:—

According to a formula deduced in Appendix (IV.),

$$\triangle P'' = \text{const.} \frac{\tau}{p} \left(\frac{w_1}{a_1} \right)^2 \frac{s}{a} \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

* Paper read before the Institution of Engineers and Shipbuilders of Scotland.

From draught gauge observations taken by the author on many trials, the constant has a value of about $\frac{1}{70,000}$, so that

$$\triangle P'' = \frac{1}{70,000}\frac{\tau}{p}\left(\frac{w_1}{a_1}\right)^2\frac{s}{a} \quad . \quad . \quad . \quad . \quad . \quad (20)$$

Applying the formula, with this constant, to the case of the economiser, where $\frac{\tau}{p} = 70$, and $\frac{s}{a}$, the surface-section, ratio is, on the average, 600 (Table VII., line 8); then

$$\triangle p_{ec}'' = \frac{70 \times 600}{70,000}(M)_1^2 = 0{\cdot}6\,(M_1)^2 \quad . \quad . \quad . \quad (21)$$

Thus, for the following values of $M_1 = \frac{w_1}{a_1}$ we may tabulate as in Table X.

Table X.

1	Mass-flow (lbs. per second per square foot) M_1 ...	1	3	6	9	12
2	Economiser draught ($\triangle p_{ec}''$) (also steam per hour per square foot of grate)	0·6	5·4	21·6	48·6	86·4 inches.

Adhering to the rate of combustion that has been adopted throughout, viz., F = 30, as given above, the steam required for the fan in pounds per hour per square foot of grate is $\triangle p$-inch. Hence the figures in line (2) represent not only the draught pressure (or vacuum) in inches of water required for the economiser portion of the boiler, but also the steam needed for its production.

For the evaporator, in which $\frac{\tau}{p} = 140$, and $\frac{s}{a}$, the surface-section ratio, has an average value of about 200 (Table VIII., line 23):—

$$\triangle p_{ev}'' = \frac{140 \times 200}{70,000}(M_1)^2 = 0{\cdot}4\,(M_1)^2 \quad . \quad . \quad . \quad (22)$$

Hence Table XI.:—

Table XI.

3	Mass-flow (lbs. per second per square foot) (M_1) .	1	3	6	9	12
4	Evaporator draught $\triangle P_{ev}$ins. (also steam per square foot of grate)	0·4	3·6	14·4	32·4	57·6 inches.
5	Total steam required per square foot of grate for fan (F = 30)... ...	1	9	36	81	144 lbs. per hour.

These draughts have been plotted, in Fig. 16, on a base of gas-speeds or mass-flow.

Useful Steam.—The amount of useful or unmortgaged steam can now be determined that will be given off per square foot of grate area, allowance being made for external radiation, and fan steam. The gross steam generated per hour per square foot of grate is F*e*. The steam spent on the fan per square foot of grate is, as will be seen in Tables X. and XI., M_1^2 lbs. per hour, when the value of F is 30. Allowing 3 per cent. of all steam generated to be wasted by external radiation, then for the useful steam per square foot of grate per hour:—

$$\frac{U}{G} = 0{\cdot}97\ Fe - fM_1^2;\ \text{or, since when } F = 30,\ f = 1;$$

$$\frac{U}{G} = 29{\cdot}1e - M_1^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

The values of this quantity, for M_1 as above, are given in the third line of Table XII. Reverting to the particular case under treatment in which 10,000lbs. of useful steam are to be provided per hour (U = 10,000), the grate area required for different draught intensities will be found as follows:—

$$G = \frac{U}{29{\cdot}1e - M_1^2}, \quad . \quad . \quad . \quad . \quad . \quad (24)$$

or with $e = 11{\cdot}82$, as above:

$$G = \frac{10,000}{344 - M_1^2}.$$

This quantity is tabulated in the bottom line of Table XII.

Part VII.—Boiler Economics.

The total annual cost to the user of a boiler plant is made up of the following items:—

I. Interest and depreciation on the first cost of:—
  (*a*) The boiler itself, including economiser, feed heaters, and pumps, feed purifying plant (if any), setting, and housing.

And of
  (*b*) The chimney or fan plant.

II. (*a*) The annual cost for fuel required for the production of the given amount of useful steam (say, 10,000lbs. per hour from feed at 60° Fah. into steam at 165lbs. absolute).
  (*b*) Annual cost for fuel to generate steam used for the fan plant, feed pumps, or other steam-using accessories.
  (*c*) Annual cost for attendance, maintenance, cleaning, and repairs.
  (*d*) Annual rental value of the land occupied by the plant.

I.—(*a*) First Cost of Boiler and Economiser.

According to the very accurate data collected from many sources by Prof. R. H. Smith (see his "Commercial Economy

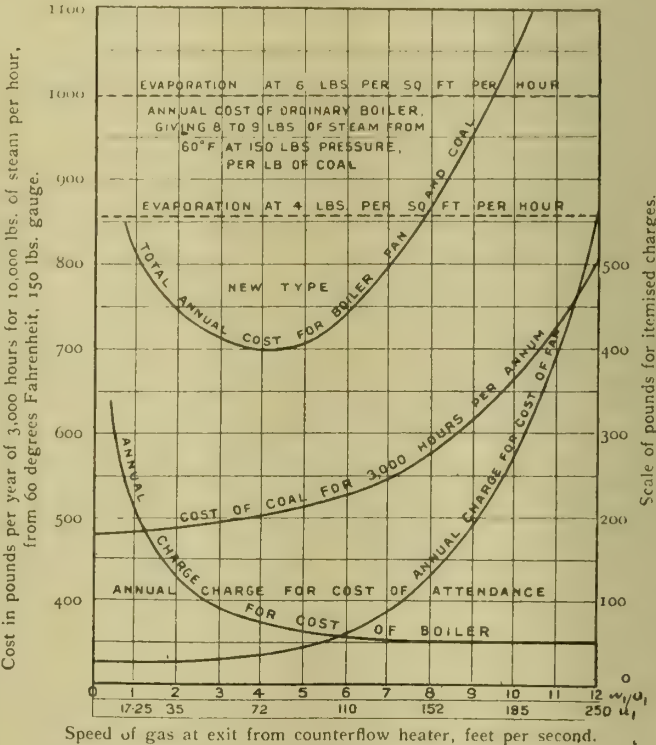


Fig. 17.

in Power Plants," Constable, 1905), the first cost of a Lancashire boiler for 160lbs. working pressure follows a linear law, which may be expressed as follows:—

$$£C = 110 + 0{\cdot}066E.$$
$$= 110 + 0{\cdot}5S \quad . \quad . \quad . \quad . \quad . \quad (25)$$

Where E = evaporation in lbs. per hour from and at 212° F.
S = total heating surface required for E, when evaporation is at the rate of $7\frac{1}{2}$lbs. (from and at 212° Fah.) per square foot per hour.

For Babcock & Wilcox boilers the cost is given by—

$$£C = 80 + 0{\cdot}078E,$$
$$\text{or } £C = 80 + 0{\cdot}33S \quad . \quad . \quad . \quad . \quad . \quad (26)$$

in which evaporation is taken at the rate of 4·2lbs. (from and at 212° Fah.) per square foot per hour.

The cost of the chimney, setting, and housing is (accord-

ing to Prof. R. H. Smith) about $\frac{1}{3}$C. Thus the total cost will be:—

$$£T = \frac{4}{3}C = 147 + 0{\cdot}666\ S \text{ for Lancashire boilers;}$$

and

$$£T = \frac{4}{3}C = 110 + 0{\cdot}44S \text{ for Babcock boilers.}$$

Taking interest and depreciation at, together, $12\frac{1}{2}$ per cent. for Babcock and 10 per cent. for Lancashire boilers, then the following expression for the annual charge for such boiler plants is obtained:—

(27) $£A_1 = \frac{1}{10}(147 + 0{\cdot}66\ S) = 15 + 0{\cdot}066\ S$ for Lancashire boilers;

(28) $£A_1 = \frac{1}{8}(110 + 0{\cdot}44\ S) = 14 + 0{\cdot}055\ S$ for Babcock boilers.

For the high-speed boilers here under discussion the annual charge at the somewhat higher rate is taken:—

$$£A_1 = 20 + \frac{S}{20}, \quad \dots\dots \quad (27)$$

where $S = (s_{ev} + s_{ec})$ G, the total heating surface.

Now for F = 30, and for U = 10,000, it was found that the grate area had the values given in Table XII., and the heating surfaces per square foot of grate had the values given in Tables VII. and VIII. Substituting in equation (27) the annual charges, as tabulated in Table XIII., are obtained.

TABLE XII.—*Gross, Fan, and Useful Steam Generated per Square Foot of Grate: when F = 30.*

Mass-flow (pounds per second per square foot) (M_1)	0	1	3	6	9	12
Gross steam less radiation, per square foot grate per hour (29·7e)	344	344	344	344	344	344
Fan steam per square foot grate per hour (M_1^2)	0	1	9	36	81	144
Useful steam per square foot grate per hour (radiation and fan steam deducted) (U/G)..	344	343	335	308	263	200
Grate area required to produce 10,000lbs. per hour of useful steam (G)	29·1	29·2	29·86	32·5	38·1	50

I.—(*b*) Cost of Fan Plant.

From particulars kindly furnished to the author by Messrs. Heenan & Froude, Ltd., and by Messrs. Sturtevant, he has deduced the following algebraic expression for the first cost of a fan plant to exhaust q thousands of cubic feet per minute of waste gas at a temperature of 220° Fah., and raise its pressure through $\triangle p''$ (inches of water) to atmospheric pressure.

Fan plant cost $= £[(100 + 5q) + (0{\cdot}1 + 0{\cdot}002q)\ (\triangle p'')^2]$.

In the present case, where F = 30, and 10,000lbs. of useful steam per hour are required, we find q as follows:—

Gas per square foot of grate per hour = F (A + 1) = 300 + 10F = 600lbs. Volume per pound at chimney temperature τ_3 is

$$V_3 = \frac{c\tau_3}{P_3} = \frac{53{\cdot}2 \times 681}{P_3} = \frac{36{,}240}{P_3}.$$

The values of P_3 are tabulated in Table XIV., and it is found that the corresponding first costs and annual charges for the fan plant are as there stated.

II.—(*a*) Cost of Coal to Furnish 10,000lbs. of net Steam.

In Table XII. was found the grate area required to produce 10,000lbs. per hour of unmortgaged steam, deduction being made of 3 per cent. for external radiation, and of an amount of steam for the fan which increased with the draught intensity. The total coal required to be burnt per hour can be found by simply multiplying these grate areas by 30; since no matter how great the draught may be through the flues, it is always maintained just enough over the fire to burn 30lbs. of coal per square foot of grate per hour. Thus the total coal burnt per hour, as in Table XV., is obtained; the coal burnt per annum allowing 3,000 working hours per year; and taking the price at 8s. per ton, the total annual cost for coal is obtained to furnish 10,000lbs. per hour of useful steam at 150lbs. gauge pressure from feed at 60° Fah., under different conditions assumed for the draught pressure.

TABLE XIII.

M.	1	3	6	9	12
Grate area for U (G)	29·1	29·86	32·5	38·1	50
Heating surfaces per sq. ft. of grate — Evaporator (s_{ev}) ...	32·62	11·57	6·32	4·56	3·68
Heating surfaces per sq. ft. of grate — Economiser (s_{ec}) ...	91·4	32·65	16·73	11·8	9·28
Heating surfaces per sq. ft. of grate — Total ... (s_1) ...	124·02	44·22	23·05	16·36	12·96
Heating surface for U (S = s G) ...	3,620	1,317	749	623	648
U/S...	2·77	7·6	13·35	16·05	16·45
Cost of boiler (T = $\frac{4}{3}$ C)	£1,606	£687	£460	£410	£420
Annual charge for capital outlay on boiler $A_1 = 20 + S/20$	£201	£86	£57	£51	£52

Total Cost.—The various items of expenditure for the generation of 10,000lbs. of steam, under different conditions of draught intensity in the flues but with the same rate (30lbs. per square foot per hour) of combustion on the grate throughout, may now be collated and their total obtained. The result is seen in Table XVI., and the various items as well as the total have been plotted in Fig. 17.

TABLE XIV.

M	1	3	6	9	12
$\triangle$p in.	1in.	9in.	36in.	81in.	144in.
p_3 lbs. per sq. in. ...	0·0361	0·325	1·3	2·93	5·2
14·7 − p_3	14·664	14·375	13·4	11·77	9·5
P_3 = 144 (14·7 − p_3)	2,111	2,070	1,930	1,695	1,367
Vol. cub. ft. per lb. (V_3) ...	17·2	17·5	18·8	21·4	26·5
Grate area for U (G)	29·2	29·86	32·5	38·1	50
Total gas per min. $\frac{600G}{60}$ ...	292	299	325	381	500lbs. per min.
Total gas 1,000's of cub. ft. per min. (q)	5·02	5·23	6·1	8·14	13·25
First cost of fan plant ...	£136	£146	£286	£619	£2,800
Int. and dep. 20 per cent....	£27	£29	£57	£183	£560

TABLE XV.

	1	3	6	9	12
Grate area...	29·2	29·86	32·5	38·1	50
Coal burnt per hour (lbs.)	876	896	975	1,143	1,500
Tons burnt per annum (3,000 hours)	1,174	1,200	1,306	1,532	2,010
Cost per year at 8s. per ton... ...	£478	£490	£522	£613	£804
$\frac{10{,}000}{0{\cdot}97 \times 11{\cdot}82} \times \frac{3{,}000}{2{,}240} \times 0{\cdot}4$	£468	£468	£468	£468	£468
Excess for fan coal	£10	£22	£54	£145	£336

TABLE XVI.

HIGH-SPEED BOILERS.					
Cost of coal per 10,000lbs. of useful steam per hour, and 3,000 hours per annum. Evaporation 11·82 per lb of coal. Coal 8s. per ton	£468				
Mass-flow rate...	1	3	6	9	12
	£	£	£	£	£
Total cost of coal	478	490	522	613	804
Annual cost for attendance, maintenance, cleaning, and repairs...	100	100	100	100	100
Annual charge for capital outlay on boiler	201	86	57	51	52
Annual charges for first cost and depreciation of fan plant	27	29	57	183	560
Total cost	£806	£705	£736	£947	£1,516

Ordinary Boiler.—For an ordinary water-tube boiler with economiser (but not counterflow) and chimney, to generate 10,000lbs. of steam per hour, at 3lbs. of steam from 60° Fah.

at 150lbs. per square foot of boiler heating surface per hour (about 2lbs. per square foot of total heating surface, *i.e.*, including economiser, per hour), the gases being discharged at 450° Fah. from the economiser, the annual cost is as follows:—

Taking chimney loss, &c., at 20 per cent.
Taking radiation loss, &c., at 3 per cent.
And assuming an efficiency of 77 per cent.

To evaporate 1lb. of water from 60° Fah. at 150lbs. working pressure requires 1,162 thermal units; hence the evaporation will be

$$\frac{14,500 \times 0{\cdot}77}{1,162} = 9{\cdot}6 \text{ lbs.}$$

from 60° Fah. at 150lbs. per pound of coal. (This equals $9{\cdot}6 \times 1{\cdot}2 = 11{\cdot}5$lbs. from and at 212° Fah. per pound of coal.)

Coal required per year of 3,000 hours for 10,000lbs. of net steam per hour is

$$\frac{10,000}{9{\cdot}6} = \frac{3,000}{2,240} = 1,395 \text{ tons per annum.}$$

At 8s. per ton the coal bill is £558 per annum. The heating surface of the boiler and economiser is

$$\frac{10,000}{3} = 3,333 \text{ square feet} = S.$$

The cost of boiler, economiser, setting, and chimney is $110 + 0{\cdot}44S = £1,576$. Interest and depreciation at 12½ per cent. on this makes the annual charge £197. Thus the total cost of steam generation from the most efficient water-tube boiler that can be made is:—

For 10,000lbs of net steam per hour during 3,000 hours a year:—

Annual cost of coal	£558
Annual charge for attendance, maintenance, cleaning, and repairs	£100
Annual charge for first cost of boiler, economiser, setting, and chimney	£197
Total annual cost ...	£855

Now the total for a high-speed boiler at the most economical gas-speed (Table XVI. or Fig. 17) is £695. Thus it will be seen that by the adoption of the new system an annual saving of £160 over the very best result now attained is secured, when 10,000lbs. of steam are generated per hour. This is equivalent to a saving of £320 per annum on a 1,000 i.h.p. installation.

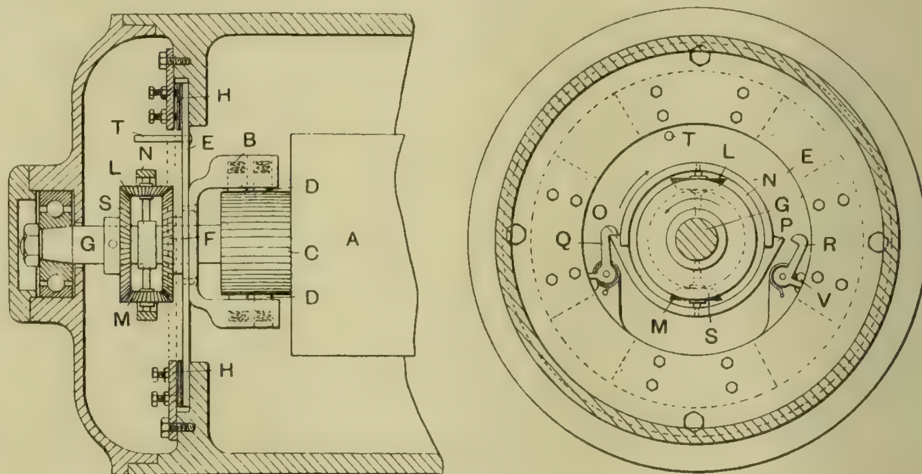
(*To be continued.*)

BRUSH-SHIFTING MECHANISM FOR DYNAMOS.

THE British Thomson-Houston Company, Ltd., 83, Cannon Street, London, E.C., in conjunction with Mr. A. P. Young, have recently patented the brush-shifting mechanism for dynamos shown in Figs. 1 and 2, the arrangement being especially applicable to variable-speed generators for supplying current for lighting or heating railway or other vehicles. In generator supplying systems of this character it is necessary to provide some means for ensuring that the current through the battery and lighting circuits will be in the same direction, irrespective of the direction of rotation of the armature shaft or of travel of the vehicles. The desired result may be obtained either by providing a change over switch in the circuit which is automatically operated from the dynamo shaft or else by rotating the brushes through an angle substantially equal to the pole pitch. In the arrangement under notice the latter of these methods is adopted and consists in mechanism adapted to automatically shift the brushes through an angle substantially equal to the pole pitch of the generator in either a forward or backward direction whenever a reversal of direction takes place.

Referring to the illustrations, Fig. 1 is a sectional elevation through the end of the generator casing showing the brush-shifting mechanism, and Fig. 2 is a cross-section. A represents the armature of the generator and B a bracket which carries the brushes D bearing on the commutator C. The bracket is rigidly secured to a disc E which in turn is secured to one of the outer wheels F of a differential gear which is loosely mounted on the generator shaft G. The disc E is adapted to be engaged by friction blocks H of lignum-vitæ which are situated between a flange formed on the inside of the generator casing and a ring secured to the casing. Locked bolts are provided to adjust the friction between the blocks H and the disc E. The intermediate wheels L and M of the differential gear are carried by an outer ring N made in two portions and provided with projections O and P at diametrically opposite points. The position of this ring is controlled by two-spring pressed pawls Q and R which are adapted to engage the projections O and P and to hold the ring against rotation at certain times. The other outer member S of the differential gear is rigidly secured to the armature shaft.

The operation of the arrangement is as follows: As illustrated the parts are in the positions they occupy when the armature is rotating in a counter-clockwise direction, if now the direction of rotation be reversed wheel S immediately reverses and tends to carry the intermediate gears L and M together with the ring N round in a clockwise direction. The ring N, however, is held against rotation by the projection O which is engaged by the pawl Q. The wheel F, and with it the disc E and bracket B, is therefore caused to rotate in a counter-clockwise direction, the friction between the disc E and the blocks H being overcome. The rotation of wheel F will continue until a pin T carried by the disc E engages the pawl Q and throws it out of engagement with the projection O after which the intermediate gears and ring will be free to rotate and the friction on disc E will hold the wheel F and bracket B against further rotation in this direction. A pin V serves to lift the pawl R out of engagement with the projection P when the direction of rotation is again reversed. It will be seen that at least one of the pawls Q or R is always in position to engage the projection O or P should the direction of rotation be reversed.



FIGS. 1 AND 2.—BRUSH-SHIFTING MECHANISM FOR DYNAMOS.

Durability of Ball Bearings.—Two ball bearings installed in one of the journal boxes of an electric car of the Atlantic City and Shore Railroad, were, after 3½ years' service, when the car had run about 150,000 miles, removed for measurement, when it was found that the mean or average radial freedom was 0·000046in., or practically nothing, and the mean end play was 0·00125in. The mean or average eccentricity of the inner race was found to be only 0·00004in., also practically nothing. The mean radial freedom for the second ball bearing was found to be 0·0003in., the mean or average end play 0·0097in., and the mean or average eccentricity of the inner race 0·00025in. The larger wear shown in the second bearing, small though it is, is accounted for by the fact that this particular bearing had to take the end thrust of the axle. It appears that during the 3½ years of service no attention was required, other than the supply of grease every 10 or 12 months.

LUBRICATING MATERIALS.

A KNOWLEDGE of the derivation and physical characteristics of different lubricants is of considerable assistance to enginemen, as it enables them to appreciate the reasons for the employment of certain oils or greases for particular parts of a locomotive. Absence of information on this subject may result in the good qualities of a lubricant being lost on account of its being put to a wrong purpose.

The primary object in using a lubricating medium is to decrease the friction between moving surfaces in contact, and next, to conduct away or tend to "cool-off" any heat generated. Undue friction will cause heating, which in turn will expand parts, &c., resulting in abrasion, and probably ultimate "seizing," as it is termed, of the details working together. Friction is actually the resistance one surface presents to another whilst being moved over it, and is due to, and is in proportion to, the roughness of these surfaces. Heat will obviously be developed if friction is allowed to exist unchecked, as all mechanical motion produces heat.

To reduce friction, lubricating materials are employed—that is to say, a film of some suitable medium is allowed to form between the working surfaces, which will prevent them coming into actual metallic contact. The "molecules," or atoms, of the material employed will develop friction, and consequently heat, amongst themselves to varying degrees; it is obviously, therefore, desirable to utilise those mediums which will develop least friction and heat under the work assigned: hence the selection necessary for different parts of a locomotive.

Practically, a journal, or piston rod, may be considered as resting or working on an infinite number of minute "globules," or balls, of lubricant, and the oils and greases which will retain and replenish these supporting balls best under heavy loads or high temperatures will prove the most satisfactory in service. The property of supporting considerable weight without being squeezed out is a requirement of a good axle lubricant for rolling stock. The work done in overcoming friction in the moving parts, if utilised for effective work, will add to the efficiency of a locomotive. All bodies, whether fluid or solid, have *some* friction set up between their molecules on movement, but some have a much lower coefficient than others; likewise some possess the valuable property of conducting away, or decreasing, the tendency to develop heat more than others.

Materials selected as lubricants should, in addition to being satisfactory in above requirements, be uniform in composition, so that they may be used with confidence; and, further, they must be neutral chemically—that is to say, they must possess no properties liable to injure metals or other materials with which they come into contact. A good lubricant should adhere tenaciously to metallic surfaces, so that it may not be easily rubbed off. If used for lubricating the steam valves, cylinders, &c., it should be capable of withstanding high temperatures without being vaporised or carbonised. Nor should a good oil solidify at ordinary low temperatures, or there may be difficulties in handling and applying it. The action of the atmosphere should not produce "gumminess" or add to the "viscosity," nor should evaporation take place on exposure to the air.

It will be appreciated from the above-mentioned attributes, sought for in lubricating materials, that few oils or greases will fulfil all; some have to be sacrificed to secure others, hence the reason why different oils are used for the various parts of machines working under different conditions. There are *three* states in which lubricants are used—viz.: (1) Liquid, as oils, employed chiefly for reducing friction; (2) semi-solid, as greases, used for similar purpose to above, and preventing heating; and (3) solids, as graphite, for forming smooth wearing surfaces, which can then be lubricated with thinner or less viscous oils.

Lubricating materials are secured from animal products (including fish), vegetable growths, and mineral deposits. The peculiar products of each are often combined by mixing or blending, and thus producing "manufactured" oil and greases which better meet requirements. Lubricants that are wholly animal or vegetable products are usually known as "fatty" oils.

Probably, on account of being first known, animal oils have been very largely used, and are even now preferred for some purposes. They exist as oils, greases, or fats: as examples, ox oil, sperm oil, lard oil, and tallow. They can be used alone, or employed to mix with and thicken other oils. They are usually obtained by melting out the fatty tissues of the flesh of animals, fish, &c., in which they are found, the product being afterwards purified to eradicate smell and prevent decomposition and change.

Vegetable oils are chiefly derived from the seeds of certain plants; they are made use of either alone or in combination with other oils. Instances of vegetable oils are rape oil, olive oil, castor oil, cocoa-nut oil, &c. They are usually obtained by crushing the seeds or the fleshy parts of the fruits of various plants, and then heating the exuded product in various ways to separate the unsuitable constituents and to purify the oil. There are two classes of vegetable oils—drying and non-drying; the former are of no use as lubricants if the drying action is at all rapid, as in oil, as they very soon oxidise and become gummy and resinous. The other kind—viz., non-drying oils, such as rape oil—are what are known as permanent liquids, or fixed oils, and are not subject to this action to any great extent.

Most of the non-drying vegetable oils are suitable, and some are unsurpassed, for use as lubricants for machinery and working parts of locomotives. Vegetable oils are not suitable for use in cylinders, as the heat there would decompose and carbonise in extreme cases, and in superheated locomotives they would be burnt. Mineral oils, which possess the property of standing great heat, have now supplanted the other oils entirely for the latter purposes.

Petroleum exists in large quantities in various parts, notably in the Caucasus, Roumania, &c., in Europe; Pennsylvania, Texas, Mexico, &c., in America; Burma, Persia, Borneo, &c., in Asia; and in the Soudan in Africa. The crude oil is obtained by methods which vary in different localities; but mostly by drilling or boring artesian wells until a "pocket" of oil is struck, when the confined gas drives up the oil with great force; quantities are often lost if adequate provision has not been made. When the pressure has decreased, the oil is pumped as required, and treated for its different products. First, it is usually allowed to settle to enable the water, which in a greater or less degree is usually present, to be removed, and also any brought up with the oil to the surface. The crude oil passes then to the distillery, where different varieties of oil are extracted, including those pre-eminently suitable for lubricating.

These latter are of different classes, and possess different properties suitable for varying needs. The less viscous oils are better for the machinery—that is, the motion, &c., whilst the more viscous oils, which are usually darker in colour, are specially applicable for use in the cylinders, as they will stand a high degree of heat without being affected.

Manufactured oils, or mixtures of light mineral oils, with animal or vegetable oils to give them "body," are very suitable for engine purposes or machinery generally, but should not be put into the cylinders, as the heat would affect the fatty components.

Generally speaking, mineral oils are safer than fatty oils, as they do not oxidise, and there is absence of danger from spontaneous combustion; they are also more uniform in quality, and purer, being free from acids; they do not "gum." If very thin they require body, however, and this can be added, as mentioned above, by mixing with other oils.

Graphite is an example of a solid lubricant. It possesses a great many merits, as it adheres well to smooth metallic surfaces, and is not affected by temperature or acids. The only difficulty that attends its use is keeping it in solution in the oil with which it is mixed. A special form of lubricator is employed in which the mixture is continually stirred up to prevent the graphite settling. By its use the minute inequalities in the faces of the parts in contact are filled up perfectly smooth. Graphite is a very pure form of carbon mined in various parts of the world. Two varieties are found—crystalline or flake, and granular or "amorphous." The former only is suitable for lubricating purposes; the latter, the more common form, being usually found mixed with sand, clay, and other impurities, which can only be separated with difficulty.—"The Locomotive."

THE BELLUZZO STEAM TURBINE.

This type of steam turbine has the high, intermediate, and low-pressure parts quite unlike each other. The high-pressure part is in two pressure stages, each with two velocity stages in series, in large units; in small units a single-pressure stage and three velocity stages in series. The intermediate pressure part is made of several discs, each with a single blade rim, and each rotating in a separate chamber, the expansion of steam taking place in the distributors of the respective rotors. The low-pressure part consists of a drum, on which are mounted several blade rings.

Such a turbine is held to possess several important thermal and mechanical advantages. It results, it is stated, in the highest thermal efficiency since, as the pressure and temperature of steam go down, the velocity of efflux from the distributors and the ratio between it and the peripheral speed of the discs also diminish, and this decreases the loss due to friction between the steam and the turbine blades. Further, the arrangement of the high-pressure discs in several velocity stages, with minimum expansion in the distributors, permits a rapid decrease in steam pressure between the stages. On the other hand, the drum on the low-pressure side makes the rotating part of the turbine more rigid.

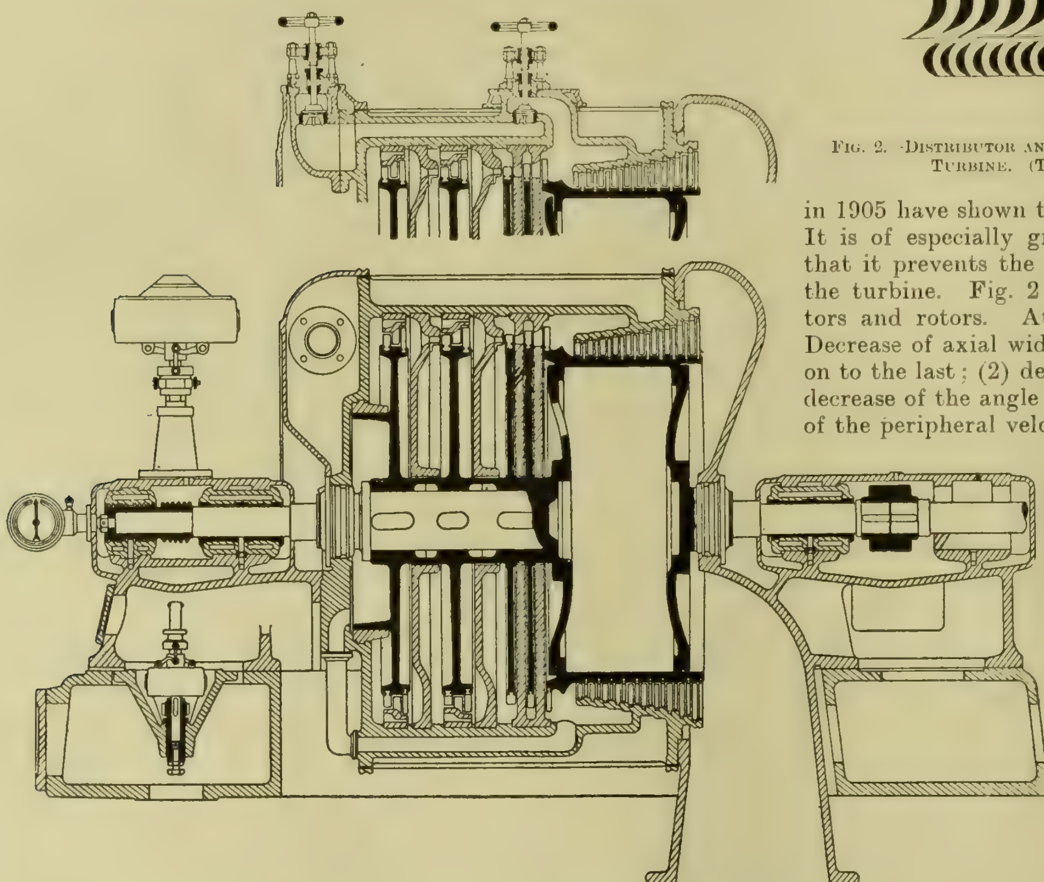


Fig. 1.—Belluzzo Steam Turbine.

The velocity of efflux of the steam from the distributors is 2,100ft. to 2,300ft. in the first stage, and 1,620ft. in the second stage; between 1,300ft. to 960ft. in the intermediate pressure part, and only about 650ft. in the low-pressure part. With such velocities wear of the blades is practically nil.

On coming from the first distributor (Fig. 1), the steam acts on the blade rim of the first disc, is deflected along the groove in the diaphragm between the two wheels, and enters the distributor of the next wheel. This arrangement prevents the steam from forming eddies when it reaches the distributor of the second wheel, due to the rebound of steam from the first wheel. The first and second wheel have partial admission, and the distributors occupy only parts of the respective peripheries, less than 90° for the first wheel, and a little more than 90° for the second. The intermediate pressure discs have also partial admission, but with a constant angle of about 180°. The radial height of blade is thus growing from one disc to another in accordance with the decrease of the velocity of steam and increase of its specific volume. From the last disc of the intermediate pressure section the steam is led to a collector, a sort of receiver between the intermediate and low-pressure parts. It has a double duty to perform. In the first instance it distributes uniformly the steam coming from the last disc of the intermediate pressure section, which has a partial admission, over the drum of the low-pressure section having full admission. In the second place it has to maintain the cast-iron walls supporting the blades of the distributors of the first wheel at a temperature slightly higher than that of the steam expanding between the discs. Tests made by Prof. Belluzzo

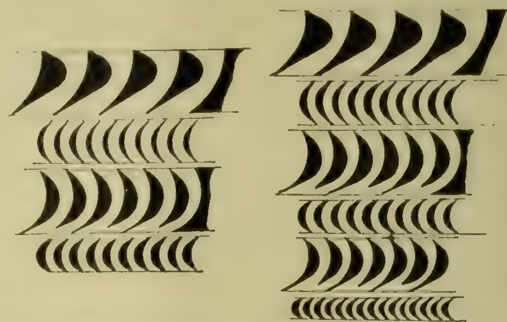


Fig. 2. -Distributor and Rotor Construction of the Belluzzo Steam Turbine. (Two and three velocity stages in series.)

in 1905 have shown the convenience of such a steam collector. It is of especially great importance for marine turbines in that it prevents the accumulation of water at the bottom of the turbine. Fig. 2 shows the construction of the distributors and rotors. Attention is called to the following: (1) Decrease of axial width of the rotor blades from the first disc on to the last; (2) decrease of the peripheral blade pitch; (3) decrease of the angle between the direction of steam, and that of the peripheral velocity; the width of the blades in velocity stages arranged in series is also decreasing. Thereby is gained the great mechanical advantage of having the weight of the blades in various discs as well as the steam pressure on the blades and the stresses due to centrifugal forces on the various discs, practically uniform.—"Proc. American Society of Mechanical Engineers."

PURE AND APPLIED MATHEMATICS.

In his presidential address at the fifth International Congress at Cambridge, Sir George Darwin remarked that the science of mathematics is now so wide, and is already so much specialised, that it may be doubted whether there exists to-day any man fully competent to understand mathematical research in all its many diverse branches. It was true that there had been in the past at Cambridge great pure mathematicians, such as Cayley and Sylvester, but they surely might claim without undue boasting that their University had played a conspicuous part in the advance of applied mathematics. Newton was a glory to all mankind, yet Cambridge men were proud that fate ordained that he should have been Lucasian Professor there. But as regards the part played at Cambridge, he referred rather to the men of the last 100 years, such as Airy, Adams, Maxwell, Stokes, Kelvin, and other lesser lights, who have marked out the lines of research in applied mathematics as studied in that University. He also made sympathetic references to the late Henri Poincaré. Proceeding, he said that both the pure and applied mathematicians are in search of truth, but the former seeks truth in itself and the latter truth about the universe in which we live. To some men abstract truth has the greater charm, to others the interest in our universe is dominant. In both fields there is room for indefinite advance, but while in pure mathematics

every new discovery is a gain, in applied mathematics it is not always easy to find the direction in which progress can be made, because the selection of the conditions essential to the problem presents a preliminary task, and afterwards there arise the purely mathematical difficulties. Thus it appeared that it was easier to find a field for advantageous research in pure than in applied mathematics. He might illustrate what he meant by reference to Lord Kelvin's celebrated investigation as to the cooling of the earth. He was not, and could not be, aware of the radio-activity of the materials of which the earth is formed, and he thought it was now generally acknowledged that the conclusions which he deduced as to the age of the earth cannot be maintained; yet the mathematical investigation remains intact. He appealed for mercy to the applied mathematician, and would ask them to consider in a kindly spirit the difficulties under which he laboured. If their methods were often wanting in elegance and did but little to satisfy that esthetic sense of which he spoke, yet they were honest attempts to unravel the secrets of the universe in which we live.

CENTENARY OF THE STEAMSHIP "COMET" AT GLASGOW.

THE citizens of Glasgow and of the other towns on the river Clyde were en fête last Saturday to celebrate the hundredth anniversary of the introduction of steam navigation by Henry Bell, who, in August, 1812, started running the small steamship "Comet" on the river between Glasgow and Greenock as a passenger vessel.

This was not, however, the first attempt to propel vessels by means of steam power. In 1698 both Denis Papin and Thomas Savery experimented with steamboats, while William Symington, in conjunction with Patrick Miller and James Taylor, tried a steam vessel 25ft. in length on Dalswinton Loch in 1789. About a dozen years later Symington placed a steamer named the "Charlotte Dundas," driven by steam by means of one stern paddle, on the Forth and Clyde Canal, but this boat had to be withdrawn because the wash of water injured the Canal banks. In 1804 Francis B. Stevens drove a small vessel with twin screw propellers on the Hudson River, and in 1807 Robert Fulton placed on the Hudson the s.s. "Clermont," 133ft. in length, propelled by an 18 h.p. engine by Boulton & Watt. Just as numerous efforts had been made by Newcomen and others to introduce steam engines before the inventions of Watt rendered the machine efficient, so there were repeated attempts to drive ships by steam before 1812; but to Henry Bell belongs the distinction of having been the first to render steam navigation a practical success in British waters. The "Comet," which was a timber vessel 50ft. in length by 11ft. in breadth and 5ft. 6in. in depth, was built by John Wood, of Port Glasgow. John Robertson, of Glasgow, constructed her engine, which was of 3 h.p., the shafting of cast iron, and fitted with a fly-wheel, and the paddles were simply four blades fixed on arms, two on either side of the boat. The maker of her boiler was David Napier, of Glasgow, the founder of the subsequent famous shipbuilding firm of that name. The "Comet" was quickly followed by other vessels of larger size and greater speed, and in a short space of time steam navigation was extended to other British rivers and deep sea vessels.

INDUSTRIAL AND TRADE NOTES.

Clyde Ironworkers and Piece-work. — The ironworkers employed in Clyde shipbuilding yards have been asked to vote on the question of striking in order to enforce an advance of 4 per cent. on riveting piece-work rates, which, it is stated, the Employers' Federation have refused.

New Wire Rope Works at Doncaster.—We understand that Messrs. Craven & Speeding Bros., of Monkwearmouth, Sunderland, propose to establish new works at Doncaster for the manufacture of wire ropes for collieries, steel hawsers, wire rigging, binder twine, and manilla ropes.

Price of Leather Belting. —According to the Federation of Leather Belting Manufacturers of the United Kingdom, there is to be a general rise of 10 per cent. in the price of leather belting throughout the country. It is stated that hides all over the world have been constantly rising in price for more than a year, and that there is a shortage of leather in every country.

Electric Furnace for the Bethlehem Steel Company. – An electric furnace of the Girod type is to be installed by the Bethlehem Steel Company, of South Bethlehem, Penn., for the manufacture of tool, armour, projectile, and other high grade special steels. It is expected that this will result in larger heats of the higher grades. The furnace will have a melting capacity of 10 tons.

Wear Shipbuilding. — During the past month eight vessels, aggregating 25,357 tons, were launched in the Wear, as compared with three vessels and 13,091 tons in August, 1911. Altogether 51 ships, totalling 190,630 tons, have been launched from the Wear shipyards this year, as against 52 vessels and 171,861 tons during the corresponding eight months of last year.

W. H. Willcox & Co., Ltd.—This well-known firm of manufacturers of engineers' tools and supplies, having, through expansion of their business, found it necessary to acquire increased accommodation, have taken a building adjoining their main warehouses, 32, 34, and 36, Southwark Street, London, viz., No. 38, at which address their registered offices will in future be situated.

Concessions to Humber Shipyard Workmen.—Negotiations between the Hull and Ouse Shipbuilding Association and the Gas Workers and National Amalgamated Union of Labour have led to advances being conceded to workers in the shipyards at Beverley, Hull, Goole, and Selby. The advances are: Helpers, 1s. per week; painters and red leaders, 6d. per week; and shipyard labourers, 6d. per week. The increased wages were paid at the end of last week.

Oil Fuel for Warships.—The Admiralty have ordered the provision of five more oil fuel reservoirs in Portsmouth Harbour, making a total of 17, while several others are said to be contemplated. At present, oil is taken from the reservoirs to the big warships in tank vessels, but instructions have been received for dredging operations to be commenced forthwith alongside the oil fuel pier, so as to enable the largest battle-ships to come and take their supply direct.

New South Wales Iron Industry.—The arrangements for the establishment by the Broken Hill Proprietary Company of iron and steel works at Newcastle have been completed. The Government will grant a 50 years' lease of a large area of Crown land, and agrees to resume the working of a private railway bisecting the land, and otherwise to assist the company. Mr. Griffiths, Secretary for Public Works, says that though it is the policy of the Government to establish State works, no obstacle will be placed in the way of the bona fide investment of private capital in useful productive industries.

Clyde Shipbuilding. — Owing largely to the launching recently of the large liners, "Niagara" and "Empress of Russia," at Clydebank and Fairfield, respectively, the Clyde shipbuilding figures for August, viz., 24 vessels of 87,599 tons, are easily the largest on record for the month. They are, in fact, just about double the August average, and, in addition, they bring the work of the year up to a total of 189 vessels of 417,551 tons. This is the second best on record, being exceeded only by that of 1907, which was larger by only about 3,500 tons.

Steam Engine Indicators. — Messrs. Schäffer & Budenberg, of Whitworth Street, Manchester, have issued a new sectional catalogue and price list, dealing with steam engine indicators and accessories. Like all the literature issued by this well-known firm, it is annoted with useful and instructive hints on the use of the various pieces of apparatus, and well illustrated, so that it constitutes a practical and useful text-book on the subject, and as such we would commend it to all steam engine makers and attendants, for, apart from its commercial value, it will be found convenient as a handy little book of reference.

Swan, Hunter's New Yard at Sunderland.—The new shipyard which Messrs. Swan, Hunter, & Wigham Richardson, Ltd., of Wallsend, are having constructed on the Wear, at Sunderland, is rapidly nearing completion, and it is anticipated that it will be possible to begin work in the yard in about six weeks' or two months' time. The site of the new yard adjoins Messrs. Priestman's yard at Southwick. It is about 12 acres in area, and when the yard is completed it will accommodate four berths. This is the first yard on the Wear to be built and run by an outside firm. The yard will provide employment for several hundred men.

Riveting Rates and Piece-work of Boilermakers.—Two questions are to be balloted on at the October meetings of the branches of the Boilermakers' and Iron and Steel Shipbuilders' Union. They are: (1) Are you in favour of giving one month's notice to cease working on piece? (2) Are you in favour of giving one month's notice to cease work altogether to enforce the special advance of 4 per cent. on riveting rates, so that holders-up may have 10½d. to the riveters' 1s.? For some time past the boilermakers have been in negotiation with the employers, with a view to securing a 4 per cent. advance on piece rates, but the employers have

refused the application, and now the executive of the union recommend that the workers should demand day rates instead of piecework.

Pistons and Piston Valves.—Messrs. Lancaster & Tonge, Ltd., of Pendleton, Manchester, the well-known makers of engine specialities, send us a copy of a new edition of their piston and piston valve catalogue. This is a line to which the firm have devoted painstaking attention for a great many years, and in the manufacture of which they may, without exaggeration, claim the premier position. The latest speciality they have introduced in this direction is an improved Ramsbottom ring, registered under the name of "Lan-Ram." The catalogue also includes several new types of pistons and piston valves, and nearly every type of ring at present in use.

Scheme for Amalgamation of Shipyard Trade Unions.—An agitation has been started in favour of one union for all shipyard and engineering workers. The agitation is receiving considerable support from the various branches of the Amalgamated Society of Engineers. A similar project was voted on a few years ago by the unions affected, and rejected by the majority of them, but negotiations are now in progress for the amalgamation of the three most important societies in the group, viz., the Amalgamated Society of Engineers, the Boilermakers' and Iron and Steel Shipbuilders, and the Ship Constructive and Shipwrights' Association.

Large Gas Engines.—Orders have recently been obtained by Messrs. Ehrhardt & Sehmer, of Saarbrücken, Germany, for the supply of two of their 4-cycle gas engines to British firms. One of these of 1,500 h.p. is for the Skinningrove Iron Company, Ltd., Carlin How, and is the fifth engine of this type they have supplied to that company. It will operate in conjunction with their patent scavenging apparatus, which enables the power of the engine to be increased up to 30 or 40 per cent. without interfering with the running or general behaviour of the machine. The other one of 2,000 h.p. is for the Barrow Hematite Steel Company, Ltd., Barrow-in-Furness, and is to be arranged so that it may be utilised for blastfurnace blowing or for the generation of electricity.

Hydro-electric Plant for Norway.—H.M. Consul at Christiania reports that, according to the local press, a well-known Norwegian company director has applied for a concession to dam up and harness the Aura and Lilledalen basins to the east of Molde, in the Romsdalen district. The plans include a dam about 130ft. high to keep back the waters of the Aurojöen Lake, and the transmission of the water thence to Sundalen either by a tunnel, affording some 197,200 h.p., or by the old bed of the Aura, providing by various combinations about 250,000 h.p. The estimated cost is about £2,110,000, and if the plans are realised this will be one of the largest hydro-electric power stations in the world.

Burdens of Legislation on Industry.—Presiding at the annual meeting at Birmingham of Messrs. Guest, Keen, & Nettlefolds, steel manufacturers, Mr. Arthur Keen said they found it necessary to increase the sum carried forward with a view to meeting the additional burdens imposed by the Insurance Act. Looking at the very large number of their employés the charge would be a very heavy one, but he preferred not to estimate. What with labour unrest and the burdens of legislation their business, in common with others, had had too much put upon it, at least in so short a time, especially as they had to contend with increasing competition at home and abroad. A resolution approving of the payment of a dividend at the rate of 10 per cent. per annum, with a bonus of 1s. per £1 share, was passed.

German Export Trade.—Mr. F. P. Koenig, in his consular report, gives some interesting details regarding the general trend of the German export trade. Coal exports increased from £16,000,000 in 1910 to £18,550,000 in 1911; coke exports from £4,000,000 to £4,650,000; briquette exports from £1,400,000 to £1,850,000. The total amount of fuel exported increased from £22,250,000 to £25,550,000. The largest increase in exports is shown by the metal industries, amounting to over £15,000,000, of which the iron and the machine industries take the largest share. The value of exports of iron and iron-made goods alone rose from £42,700,000 to £51,200,000, or an increase of £8,500,000. Electrical goods and machinery appear to have found severe difficulty in increasing their exports.

The Derwent Valley Water Scheme. — The first instalment of the new Derwent Valley water scheme, by which the needs of Sheffield, Nottingham, Leicester, and Derby will be supplied, was opened last Thursday week. The scheme, which is of an extensive character, is being proceeded with in three instalments, the first of which comprises the Howden and Derwent reservoirs, estimated to give a daily supply of at least 13 million gallons. The Howden reservoir is a mile and a quarter long, and is capable of holding 2,050,000,000 gallons, whilst the Derwent reservoir is a mile and three-quarters long, and will hold upwards of 2,000,000,000 gallons. The only reservoir in the second instalment will be that of Hagglee, and the Ashopton and Bamford reservoirs will form parts of the third instalment.

Telephone Trunk Charges. — Following an announcement by Mr. Herbert Samuel, reduced rates for the use of trunk telephone lines during the slack hours of the day have come into force. The slack hours are before 10 a.m., between 1 and 2 p.m., and between 4 and 7 p.m., and the reduced charges for conversations longer than the customary six minutes are: First and second quarter-hour periods, three-quarter full trunk charges. Third and fourth quarter-hour periods, half trunk charges; each additional hour, quarter the full trunk charges. The minimum time allowed under these charges is 15 minutes, and each subscriber taking advantage of the facilities will be obliged to sign an agreement for a period of at least a month.

Large Oil-engined Vessels.—Messrs. Krupp's Germania Dockyard at Kiel is, we learn, building for the German branch of the Standard Oil Company the largest oil motor-driven vessel yet constructed. It will have a carrying capacity of 15,000 tons, and will be the largest "tank steamer" afloat. Hitherto the vessels built for the transport of oil from America to Europe have carried only 8,000 tons. The new ship will be 420ft. long and 65ft. beam. It will be propelled by two simple Diesel engines. These will develop 1,800 h.p. and will propel the ship at a speed of 10 knots. Fourteen motor-ships, ranging in tonnage from 4,500 to 15,000, are now said to be under construction in Germany. The "Selandia" (Danish East India Company), the largest motor-vessel afloat, is 7,000 tons, and her success has led the owners to order two vessels of 10,000 tons. Five oil-driven vessels of 10,000 tons are also said to be under construction for the Italian General Navigation Company.

The Panama Canal and Future Trade Routes.—The remarkable effect which the Panama Canal will exercise on trade routes in future will be seen from a comparison of the following figures of distances of various ocean routes: Before the opening of the Suez Canal Liverpool had an advantage of 480 miles over New York in trade with Asiatic and Australian ports round the Cape of Good Hope, and the Suez Canal extended this advantage to 1,924 miles. The opening of the Panama Canal will not alter much the relative distance to Asiatic ports south of Shanghai, but the route from Yokohama to New York viâ Panama will be shorter than that from Yokohama to Liverpool viâ Suez by 1,805 miles. The same comparison applied to Sydney will give New York an advantage of 2,382 miles over Liverpool. In the case of Wellington the advantage will be 2,759 miles, which means that the Australasian dominions, now a thousand miles steaming nearer to Liverpool than New York, will soon be 2,500 miles steaming nearer to New York than Liverpool.

North-East Coast Iron and Steel Exports.—The Middlesbrough Customs return of the shipments of pig iron, manufactured iron, and steel from the Tees for August shows remarkable activity. The quantity exported reached 183,890 tons. The best month this year so far for pig-iron shipments has been March, when 131,255 tons were sent away, but for manufactured iron and steel exports the past month has not been surpassed. Scotland took 21,025 tons of pig iron mainly for the foundries on the Clyde, and, as showing the activity of trade on the Continent, 7,067 tons went to Belgium, 8,813 tons to Germany, 3,435 tons to Holland, 11,316 tons to Italy, 7,409 tons to France, 7,098 tons to Sweden, and 2,680 tons to Russia. Japan took 9,967 tons and the United States 3,000 tons. The manufactured iron and steel exports consisted chiefly of railway and constructional material. India took 14,000 tons, Argentine 8,500 tons, Cape Colony, Natal, and Portuguese East Africa 8,000 tons, New Zealand 5,000 tons, and New South Wales and West Australia 17,900 tons.

Miners' Notices — Important Test Case.—A decision of the greatest importance to the mining community was given in the Ystrad Police Court on Monday last. The Stipendiary gave judgment in the case of Amos v. Glamorgan Coal Company, which tested the legality of 24 hours' notice for miners. The Stipendiary said that after Lord St. Aldwyn's award the parties were never of one mind as to the length of notice, and there was no actual agreement between them now, nor did he think the matter was governed by custom. Length of notice had so long been a matter of general contract in the district as to exclude custom altogether. No single instance was given of a colliery where customary, as distinct from contractual, notice prevailed. In the absence of agreement of custom on the point, he fixed reasonable notice at four weeks, and gave judgment for the plaintiff, who claimed £10, for four-sevenths of the amount, viz., £5. 14s. 3d., with costs. The Stipendiary expressed willingness to state a special case, and it is understood the matter will be carried to the House of Lords.

Cleveland Miners Dissatisfied with the New Explosives Order.—Strong complaints against the adverse effects of the new Explosives Order in Cleveland were recently addressed to the Executive of the Cleveland Miners' Association at their meeting at Saltburn. The committee expressed themselves dissatisfied with the delay of the Home Office in holding an enquiry into the special conditions of Cleveland, as asked by the Mineowners' and Miners' Association, and it was resolved to suggest to the mineowners that a further joint letter be sent to the Home Secretary strongly urging the need of an enquiry at the earliest possible date, with a view to secure the exemption of Cleveland from the operations of the Order, or much-needed modifications. The Executive discussed the action of certain managers under the Order in sending men out of the mine in the event of shots misfiring and not allowing them to remain the hour—which the Order specifies shall elapse before a person can return to a place where a charge has not exploded—and then resume work. The committee held that under existing hiring conditions managers were not justified in sending men home, and they resolved to advise miners not to leave the mine, but to wait until the hour specified by the Order had elapsed, and then resume work, and finish their shift.

Electrical Smelting of Iron Ore in Norway.—A report of H.M. Consul at Christiania states that the Hardanger Electric Ironworks started in November, 1911, and during a short spell of activity produced rather over 300 tons of raw iron, which were exported. The ore smelted came from the Klodeberg Mine near Arendal, containing 40 to 45 per cent. of iron. The ore furnace is calculated for a maximum of 3,500 h.p. Further experiments are to be made with ore from Rödsand. A new electric mass furnace is being made, to act at first as a reserve furnace, and an electric steel furnace will probably be constructed during 1912. The Arendal Fossekompagni has projected iron-smelting works near Arendal, and is to employ 8,000 h.p. It is hoped to begin working on ore from the fields near Arendal and Lyngör in the spring of 1913. The Tinfos Ironworks for electric smelting will soon begin output, but have been delayed by a lock-out and other causes. The Stavanger Electric Steelworks, for the manufacture of steel from old battle-ships, &c., will probably not start working before the latter half of 1912; they will employ some 1,000 to 1,500 h.p. Hammering works are under construction. From the above it will be seen that electric iron smelting in Norway is still, comparatively speaking, in its infancy, but several new works of the kind are already under consideration.

Effect of Legislation on Engineering Industries. — At the autumnal meeting of the Association of Chambers of Commerce to be held at Newcastle next week, Mr. A. G. Hobson, Lord Mayor of Sheffield, will present an important contribution on the influence of the Workmen's Compensation Act and the Old Age Pensions and National Insurance Acts on the cost of engineering manufactures. He points out that the additional cost to the great engineering industries of this country, owing to the Workmen's Compensation Act, in the last two years has increased by 52 per cent. compared with the five years from 1902 to 1906 inclusive. Producers, he says, are therefore faced with an increased cost for workmen's compensation and health insurance of 1·77 per cent. on their wages bill. "Nearly all the materials they buy will," said Mr. Hobson, "be affected by similar considerations, and I do not hesitate to say that the price of materials will be generally lifted at least 2½ per cent. The prudent firms who look carefully into the cost of the articles they manufacture will be bound to raise their selling price by 2½ per cent., and they will be assisted to do so by what appears to me the very important effect of the National Insurance Act and Workmen's Compensation Act." Figures, which Mr. Hobson gives, show that in 1902-6 the percentage of insurance premiums in wages was 0·61, while in 1911 it had increased to 1·19, giving an average of 0·99 per cent. for the years 1907 to 1911 inclusive.

Employment of Unskilled Workmen on Semi-Automatic Lathes.—The Executive of the Amalgamated Society of Engineers have called out 200 engineers from their employment at the works of Messrs. John Lynn & Co., of Pallion, Sunderland. This step has arisen as a result of the decision of the society that only skilled men shall be employed in the working of the semi automatic lathes. This action on the part of the society indicates the approach of a serious impasse in the engineering and shipbuilding industry. Three special conferences between the Engineering Employers' Federation and the engineering trade unions have failed to settle difficulties arising out of the manning of new machinery. In accordance with the policy decided upon as a result of this failure of arbitration, strikes will be sanctioned by the trade union executives in all engineering centres where employers introduce handymen on new machines. The employers claim that under the Terms of Agreement, 1907, they have the right to select, train, and employ those whom they consider best adapted to the work, irrespective of apprenticeship, and to pay them according to ability; and it is suggested that the unions desire to restrict the adoption of improved machines and limit the output. On the other hand, the unions hold that skilled men should be employed on the new machinery at standard rates of wages, and that semi-skilled machine operators shall serve an apprenticeship of at least four years, commencing before they are 18 years of age.

British Trade with Norway.—The British Vice-Consul at Bergen, in a report on the trade of that district in 1911, suggests that British business managers and partners, who wish to develop their trade with Norway, might perhaps with advantage follow the example of some of their commercial rivals by undertaking personal visits to Norway with greater frequency than now appears to be the case. Cases are known where this method has been attended with great success in other parts of the world, and more than one business man in Bergen has told the Vice-Consul that he would certainly feel more disposed to do business with a firm if he were in occasional personal relations with its head. Such a visit should be stimulating to resident agents, and need not interfere with the regular work of the firm's travellers, to which it would be supplementary. As regards the classes of goods in which the United Kingdom does not appear to be getting her fair share of business, the most noticeable are electrical appliances and motor-cars.

Flexible Metallic Tubing.—The sterling advantages of this now well-known form of tubing for many services wherein the ordinary flexible type of tubing, owing to the pressure, temperature, or nature of the fluid, would be worthless, has led to its wide adoption in a variety of directions, and flexible metallic tubing has become in innumerable cases a necessity. Some illustrations of the multiplicity of service in which it is employed are furnished in a circular just issued by the United Flexible Metallic Tubing Company, Ltd., of 112, Queen Victoria Street, London, E.C. The tubing is unaffected by heat or cold, and remains flexible at all temperatures; it will stand exposure to any kind of weather and to every variety of climate. It is not liable to the attacks of vermin or insects and it will not char. Moreover, it does not kink or crush, and thus it always delivers to its full capacity, and so assures a relatively larger service than rubber, linen, or leather hose of equal sectional area. Owing to the recent improvements introduced into the manufacture, it has become possible to supply pipes of almost every size up to 12in. internal diameter. For the conveyance of petroleum and other oils, or greasy liquids, which speedily attack rubber, this tubing gives the best possible results, as the flexibility is improved by the lubricating action of the liquids passing through it. Within the memory of many engineers, now only of middle age, such pressures as 100lbs. per square inch were considered to be very high, while working pressures of 300lbs. and even 200lbs. were practically undreamt of. Under the old conditions it was possible for rubber hose to be used in many cases to convey steam; but now that increased pressures, naturally engendering much greater heat, have become so widely prevalent, no tubing made from cloth, rubber, or indeed from any vegetable substance, will withstand the heat and strain for any appreciable length of time. The Bronze No. 2 tubing is constructed to stand steam pressures of 300lbs. per square inch, while special tubes to withstand even greater pressures than this can be supplied.

Trade Circulars and Catalogues.—We beg to acknowledge receipt of the following trade circulars and catalogues: From Messrs. Mather & Platt, Ltd., Salford Ironworks, Manchester, descriptive circulars of standard cast-iron tanks, built up from stock, and of centrifugal pumps combining the advantages of the volute and turbine designs, and either belt or motor driven, for general purposes.—From Goodchild & Partner, 30, Farringdon Road, London, E.C., a circular giving some descriptive notes on threading tools and their upkeep for the benefit of works managers and foremen. The notes are interesting and instructive, and may be perused with advantage by all who have to deal—and what mechanical engineer has not?—with the use and formation of screw threads.—From Frederick Braby & Co., Ltd., Eclipse Works, Petershill Road, Glasgow, catalogue of galvanised roofing sheets, sheet-iron tanks, doors, windows, fastenings, and other kinds of iron building accessories.—From The Bromell Patents Company, Ltd., 62, Robertson Street, Glasgow, catalogue and price list of several boiler-house specialities, in the shape of valve reseaters and facers, tube cutters, and cleaners of various kinds for smoke tubes, condenser tubes, &c.—From Souper & Callaghan, 16, Deansgate, Manchester, circular of a combination tool which comprises on a single bed-plate a rotary blower forge, an anvil, a mechanic's vice, an emery wheel, and a drill press.—From W. A. Walber & Co., 38, Victoria Street Westminster, a catalogue of the "Thule" high speed shaping machines, the special features claimed for which are the extreme lengths of the feeds, and the useful range of attachments for various work. The machines are built in four sizes, having 14in., 16in., 20in., and 25in. stroke, respectively.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Internal-combustion engines. Alston & Houston. 11230.
Ignition systems and apparatus therefor. Kettering. 11292.
Controlling railway points and signals. Descubes. 14059.
Treating carbonaceous materials for the production of coal gas and water gas. Royston. 15964.
Reducing or limiting the effects of explosions in coal mines. Wetter. 18210.
Cooling apparatus for the cylinders of internal combustion engines. Smith, Whitely, & Spencer. 18221.
Carburetters for internal-combustion engines. Bainbridge. 18246.
Controlling the admission and exhaust of internal-combustion engines. Thomson. 18252.
Valves. Russell. 18344.
Turbines. Sauer. 18368.
Fluid-pressure engine or compressor. Donaldson, Seabrook, and Berry. 18371.
Refining molten pig iron for steel-making purposes. Twynam. 18406.
Speed indicating devices. Mattinson. 18475.
Valves for compressors or pumps dealing with gaseous or fluid substances. Workman and Murray, Workman, & Co. 18478.
Lubricant pumps. Daimler Motoren Ges. 18618.
Ball retainers for ball bearings. Aktiebolaget Svenska Kullagerfabriken. 18662.
Guards for preventing the splashing of oil from the cranks of gas engines. Ditchfield. 18683.
Apparatus for burning finely-divided fuel. Babcock & Wilcox, Ltd. 18712.
Valves and valve seats. Lamb & Clegg. 18724.
Steam engines having a superheater. Fowler & Livsey. 19030.
Couplings for shafts. Thompson & Kildear. 19503.
Apparatus for handling ore. James. 19676.
Mechanism for distributing liquid for lubricating purposes. Degang & Philippe Guillemaud et Fils. 19789.
Apparatus for raising and forcing water. Cardella. 19880.
Method of generating gas. Jordy & Harting. 19960.
Means for separating and removing liquid impurities from gases. Carter. 20757.
Hydraulic transmission apparatus. Schneider. 21078.
Self-oiling roller-bearing wheels and pulleys. Samuel Osborn and Co. and Laister. 21563.
Cylinder water-cooling arrangements in internal combustion engines. Webber. 21659.
Valves for supplying liquid fuel and air to internal-combustion engines. Moon & Burnand. 22267.
Boiler flue covers. Evers. 22601.
Lubricators for internal-combustion engines. Smith. 22677.
Railway signalling systems. Buell. 22781.
Rotary explosion motor. Beck. 22798.
Air-compressing devices. Mann. 22865.
Anvils for pneumatic riveting machines. Olsen. 23137.
Devices for measuring the wear of railway rails. Grierson. 23820.
Rails, especially tramway rails, for preventing the formation of corrugations. Zell. 23859.
Starting gear for internal-combustion engines. Coleman & Rawlings. 24508.
Internal-combustion motors. Losey. 24628.
Flexible band couplings. Fischer. 25322.
Acetylene generators. Butterfield. 25527.
Lubrication of engines. Mavor & Coulson, Ltd., and Mavor. 25644.
Process and means for producing bolt and rivet heads. Muller. 25713.
Apparatus for reversing hydraulic couplings. Marks. 26120.
Controlling devices for hydraulic transmission apparatus. Soc. Schneider et Cie. 26738.
Steam traps. Dewrance. 27258.
Apparatus for arresting the descent of pit cages in case of emergency. Rowbotham. 28218.
Turret lathes. Herbert & Vernon. 28440.
Arrangement and disposition of parts of internal combustion engines. Gold, Beeching, & Kynoch, Ltd. 28776.
Switches for mono rail telpher tracks. Robert Dempster & Sons, Ltd., and Mitton. 29062.

1912.

Application of the internal combustion engine to the driving of machines. Baker. 773.
Variable velocity power transmission devices. Louis. 2160.
Railway signalling systems. Minnick. 2436.
Furnaces. Anderson & Bullick. 2749.
Clutches chiefly applicable to tool holders. Weaver. 4440.
Bearings for reciprocating or oscillating parts of engines or machinery. Jones & Kynoch, Ltd. 5179.
Fittings for the fronts of furnaces. Bennis. 5189.
Rotary internal combustion engines. Pearson. 5546.
Liquid fuel furnaces. Dahl. 7132.
Railway points or switches. Wooley. 7286.
Heating furnaces. Nice. 7354.
Railway rail joints. Pyke. 7854.
Valve gear for steam engines. Mumford & Anthony. 8178.
Track apparatus for interaction with moving trains on railways. Soc. d'Electricité Mors. 8186.
Gear grinding devices. Weaver. 8705.
Apparatus for filtering air or gases. W. F. L. Beth. 8752.
Condensers for use in acetylene gas plants. Green. 9152.
Rotary blowers or pumps. Green. 9613.
Screwing attachment for drilling machines. Wilson. 9805.
Fluid-pressure power transmission. Brun. 11258.
Steam superheaters. Schmidt'sche Heissdampf-Ges. 12029 and 12030.
Combined pressure-regulating and stop valves. Moll. 13414.
Double membrane pump. Koven. 14127.
Regenerative cooking ovens. Soc. Anon. Burkheiser-Eloy. 16226.
Coupled or twin steam engines. Smal. 16250.
Railway safe running devices. Angus. 15900, 16624, 17175, 17269, and 17938.

ELECTRICAL, 1911.

Electrical conduit junction boxes. Gatis. 15866.
Electric heating apparatus. Bastian. 16143.
Application of electric currents for preventing the corrosion of the tubes of surface condensers. Harris. 18220.
Electrical heating element. Judd & Riley. 18334.
Manufacture of metal filaments for electric lamps. Grote. 18351.
Manufacture of filaments for incandescent electric lamps. Hoge and "Z" Electric Lamp Manufacturing Company. 18392.
Sparking plugs of internal-combustion engines. Johnson. 19800.
Electric heating apparatus. Holmquist. 21026.
Fittings for incandescent electric lamps. Gunn and W. T. Nicholson & Clipper Company. 26377.
Electric safety lamp. Sefton-Jones. 27826.

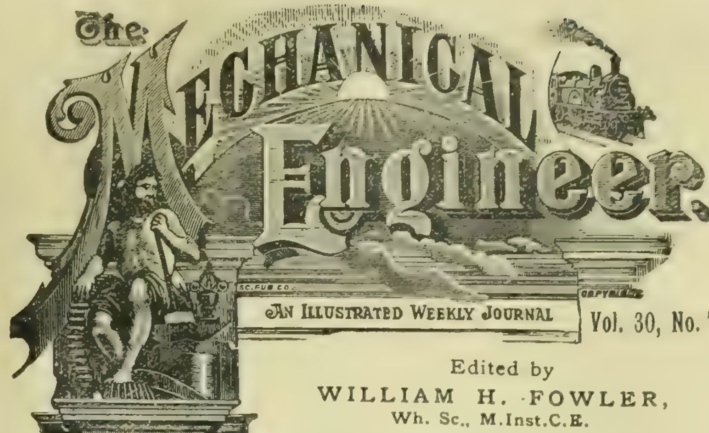
1912.

Mechanical connectors for electric cables. Neave and Callenders Cable and Construction Company. 163.
Sparking plug for internal-combustion engines. Stevens. 2467.
Method of ignition in internal-combustion engines. Gasmotoren Fabrik Deutz. 4167.
Electric switches. Murray. 6112.
Electric motors. Girardelli. 6496.
Electricity meters. Siemens-Schuckertwerke Ges. 6647.
Restraining the augmentation of an electric current. Hazlehurst and Longstreth's, Ltd. 6882.
Electricity meters. Isaria Zahlerwerke Akt.-Ges. 8075.
Oil-brake electric switches. Barbour & Travis. 10528.
Electric switches. Fairweather. 10704.
Clutch gear for Hughes telegraph apparatus. Siemens Bros. & Co. 12313.
Electric switches. Siemens Bros. Dynamo Works, Ltd. 12980.

METAL QUOTATIONS.

TUESDAY, SEPTEMBER 3rd.

Aluminium ingot	80/- per cwt.
" wire, according to sizes, &c. ......from	102/- "
" sheets " " ...... "	120/- "
Antimony ...... £28/-/- to	£29/-/- per ton.
Brass, rolled	8⅛d. per lb.
" tubes (brazed)	11½d. "
" " (solid drawn)	9¾d. "
" " wire	8⅝d. "
Copper, Standard	£79/2/6 per ton.
Iron, Cleveland	64/1½ "
" Scotch	70/1½ "
Lead, English	£21/7/6 "
" Foreign (soft)	£20/17/6 "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£8/5/- per bottle
Silver	28⅞d. per oz.
Spelter	£26/10/- per ton.
Tin, block	£217/15/- "
Tin plates	14/9 "
Zinc sheets (Silesian)	£29/10/- "
" (Stettin; Vieille Montagne)	£29/17/6 "



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Edited by
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University Training.

The Congress of the Universities of the Empire has, unfortunately, not received the attention it deserves. No doubt there are many contributory reasons for this neglect, but one reason is undoubtedly that the world, and particularly the business, commercial, and technical world is not deeply convinced that the university of to-day is something that really matters. The existence of this feeling makes it all the more regrettable that the occasion of the Congress has not called forth more criticism from the lay world. If such criticism were well considered and thoughtfully received it would advance the cause of higher education one step further on the road to a wide and far-seeing utility which it is alleged it does not now possess in any considerable degree. The business man to-day is, however, shy of voicing his dissatisfaction with modern university training. Twenty, and even 10 years ago he was less reserved, but, as a result of a vigorous campaign mainly on behalf of technical education, in which many leading public men have taken part, he has been half converted and constrained to lip-service in the cause of higher education. Already, however, there is a reaction, and the technical press contains frequent criticisms of higher education in general, and special features in particular. It is only by meeting criticisms, acknowledging defects, and accepting improvements that progress can be made, and in this spirit it is proposed to offer a few comments upon modern university training, particularly as it affects engineers and business people.

In business it is common to hear it remarked that systematic methods are essential both in the office and in the works, but that it is a mistake to have too much "system." In other words, every extension of system which facilitates the attainment of the legitimate objects of the business is valuable, but as soon as one begins to think of the system as something apart from one's business, as something to be polished and perfected for its own sake, it is time to call a halt, and take stock of one's position and attitude. So, too,

in the case of higher education. Behind all the discontent there is a very strong feeling that the simple elementary education which served the working world fifty or more years ago is not sufficient to-day. It does appear, however, that knowledge is being too much considered for its own sake, and not in the light of its influence on its recipients. This must not be construed into an attack upon scientific research, with which we are not concerned in the present article. University training approximates in its character too much to that of an encyclopedia and too little to that of a craft. The difference is radical. In an encyclopedia you expect to find a more or less complete discussion of everything within the field covered by the encyclopedia. Absence of a few items condemns it, although some may be admirably treated. Moreover, each item stands more or less detached from the rest, like stones before the building has been commenced. A craft, whether of the hand or the brain, is the opposite of an encyclopedia. It covers a very much smaller field, and ignores many things which do not possess any particular relationship to the whole. Relationship is, indeed, an essential feature. Each item rests upon its fellows, and hence there are none of those omissions which seem too trifling to be worthy of separate notice in the encyclopedia, but which in practice form the links which convert a mob of facts into a disciplined army with a purpose and value in life. The difference between the encyclopedist and the craftsman in practical life is this. The encyclopedist is a reference, a signpost. In short, he is passive. The craftsman, on the other hand, is active. He can do things, and getting things done is half the battle in practical life.

On the other hand it must be recognised that there are two opposite tendencies at work modifying modern industrial life. One is the increasing specialisation both of product and individual labour; whilst the other is the growing demand for a wider outlook on the part of those who direct industrial operations. The tendency towards specialisation is all in favour of the craft type of education in the lower grades of labour, and very largely so in the higher grades. The need of a wider outlook in the higher grades calls for a much more encyclopedic knowledge, but it also calls for a considerable measure of the craft training by which the isolated data of the encyclopedia can be co-related and translated into practice. Craft training in this connection does not necessarily involve any form of manual work. The essential thing is that it should present knowledge in the form of a map, with each item in its proper relationship, both as to position and magnitude, to the others. Given moderate courage and general ability a man who possesses a blending of encyclopedic information and craft knowledge is capable of wisely directing the affairs of an industrial concern in a manner far superior to one who has had no higher education or only such as is of the encyclopedic kind.

It may be said that such higher education is too narrowly technical, and fails to give that wider culture and development which our older universities attempted, and which is to-day frequently advocated under the motto "knowledge for knowledge sake." On the contrary knowledge for its own sake pre-eminently fails to give a wide culture, and it is to remedy this defect and to secure the best results of the older system that the strengthening of the craft outlook is recommended. The strength of the old so-called classical university training was its study of the actions of men in the varying circumstances, whether difficult, dangerous, or merely ordinary, of life. It was the nearest approach to craft training for the higher walks of life which was then available, and the failure of present-day scientific training is largely accounted for because it sets up the encyclopedia as its model to the exclusion of the old classical or craft idea. It is still true, and probably always will be, that a large part of life in responsible positions is non-technical, and hence in addition to the technical side of a university training the human side is of great importance. There are many ways of encouraging this wider training, not all of them class-room methods; but one which is not sufficiently appreciated is the desirability of gradually throwing on to the students the government of themselves.

Examinations are still a bone of contention. Most people profess to dislike them, but nearly all rely upon them. It is urged against them that they are no test of practical ability and intellectual capacity. The reason for this seems to be that the training given is of the encyclopedia type, and although an examination constitutes a fair test of the training, we have seen that the training itself is defective. When the training partakes more of the nature of a craft so that the student is taught to give due weight to each item of knowledge as a part of a connected whole which cannot be understood from a study of the items separately, the examination will change to suit the training, and will be a correspondingly better test of the value of the student's attainments. No doubt examinations suffer from inherent defects, but their chief defect to-day is that they reflect a defective system of training. When the training is improved the examination will be a truer test of fitness. Whilst on the subject of examinations something ought to be said regarding the rigidity of many of these, particularly in the case of matriculation and entrance examinations. The value of these turns upon their ability to determine the quality of the student's mind. It is not right that a capable student should be failed because his abilities don't run to languages or fall short on history or science. No single subject whatever is essential for a general examination, and there ought to be the widest possible choice of alternative subjects. Political economy is as valuable an index as chemistry, geography as English grammar, and descriptive industrialism as any language, dead or alive. The chief condemnation of higher education is to be found in the narrowness of highly educated people who can see no good outside their own subjects.

THE FACTOR OF SAFETY IN MINE ELECTRICAL INSTALLATIONS.*

BY H. H. CLARK.

A FACTOR of safety may be regarded as representing the ratio of maximum capacity to average duty. Factors of safety are used in the solution of engineering problems in which the conditions cannot be exactly determined in advance, or in which unforeseen happenings may arise to introduce severe stresses. Especially does this apply to problems in which the safeguarding of human life is a consideration. The safe operation of electrical mining equipment is an engineering problem that involves the element of human life, and that is influenced by conditions and events that cannot always be foreseen. The successful solution of the problem will therefore depend largely upon the factor of safety that is considered in the selection, installation, and maintenance of such equipment.

In problems in which the factor of safety can be expressed numerically, it is seldom made less than three and often more than 30. In the present discussion the factor of safety cannot be numerically expressed, because neither the capacity for safety nor the duty to be performed in preventing accidents can be measured in the same terms, or even in any terms at all. Therefore, more care, better judgment, and more liberal allowances in design, construction, and installation are required to ensure a factor of safety than would be required if its existence were susceptible of mathematical proof. To facilitate consideration, the problem may be divided into two principal parts: First, an analysis of the conditions to be

* From a paper issued by the United States Bureau of Mines.

met; second, a discussion of how to meet them and ensure a desirable factor of safety.

In analysing the relation that the use of electricity in mines bears to the accidents that occur there, the first step is to classify the different ways in which electricity can cause injury, death, or disaster. One characteristic of the electric current with which everybody is familiar is its ability to produce electric shocks. The conditions underground are favourable to their occurrence. There is a well-known fire risk in connection with the use of electrical apparatus. The use of electricity in the vicinity of gas, explosive dust, or explosives, all of which may be found in mines, is attended with danger. There are, therefore, in connection with the use of electricity in mining work three possible dangers—shocks, fires, and explosions.

The conditions under which electricity can start a fire or cause an explosion may be absent from a mine at any or all times, but the chance of receiving an electric shock is always present in any mine where electricity is used and men are at work. Many conditions that are peculiarly favourable to the occurrence of electric shocks are found in mines. Most of these, such as dampness, dust, limited space, and scanty light, are unavoidably associated with mining work. In addition, many underground employés are unfamiliar with electrical apparatus and the proper way to regard it.

Under the best of conditions ground-return circuits offer more chances for shock than do completely insulated circuits. The risk is increased where workmen are obliged to stand upon the ground when handling apparatus operating with ground returns. In ground-return systems one side of the generator is connected to the earth, to the track-rail network, and to the return feeders which are in parallel with both. As a result, anyone who stands upon the ground stands upon one side of the electric circuit, and only a single contact with the other side of the circuit is necessary to give a shock.

Apparatus that has accidentally come in contact with the ungrounded side of an electric circuit is almost as dangerous as a trolley wire. If such apparatus is metallic and is insulated from the earth, it offers all the necessary conditions for giving a severe shock, and the danger from such a shock is accentuated by the fact that the victim, being unaware of his proximity to danger, may firmly grasp the charged part. If a shock is received while the victim is grasping the source of current, the results are more likely to be severe than under other conditions, because the grasp is "frozen" in place by the sudden contraction of the muscles, and voluntary release from contact with the circuit is impossible. By connecting to the earth such parts of apparatus as are made of conducting material but are not designed to carry current, they cannot become charged with electricity to a potential above that of the earth; consequently, a shock cannot be obtained by a person's establishing contact between such parts and the ground.

The danger from fires caused by electricity arises principally from defective installation, careless upkeep, or from injuries to equipment resulting from falls of roof or similar causes. A short-circuit or an earth that does not blow the circuit-breaker nor the fuses may produce heat enough to start a fire by leaking across coal or timbering. The blowing of an open fuse is accompanied by sufficient heat to ignite combustible material that is very close to the fuse, especially if for any reason the arc is long drawn out. The presence of inflammable material around electric motors or starting boxes may prove to be a source of trouble. Incandescent lamps produce heat enough to ignite combustible materials if the dissipation of heat from the bulbs of the lamps is allowed to become restricted. With conductors bare and with both sides of the circuit strung side by side, there is a chance that leakage from one side to the other across coal or damp timbering may produce heat enough to start a fire.

The conductivity of coal, especially dry coal, is usually very low. This fact tempts careless workmen to poor construction and poor installation; also it aids in covering up these defects. Such poor work might be logically expected were it not for the fact that, under some conditions, earths to coal will produce sparking, arcing, and heating enough to start fires. Inflammable material should never be allowed to collect about a motor or in the vicinity of fuses or other apparatus that can produce arcs, flashes, or considerable heat. To provide a factor of safety, starting boxes, fuses, and all apparatus that may throw off sparks under normal conditions, or that are subject to abnormal conditions that result in the production of even greater heat, should be mounted on or protected by a sheet of metal or other strong non-combustible material.

Explosions may be caused by the ignition of explosives, gas, or coal dust. Accidents due to the ignition of explosives by electricity may be divided into two classes: Those that occur while handling and transporting explosives near electric circuits and those that are incident to the detonation of explosives by electrical means. As to accidents of the first class, electricity is no more of a menace than any other source of flame and heat.

Electric sparks will ignite mine gas and air mixtures that contain between 5 and 11 per cent. of gas (methane). Between these limits a comparatively small spark is sufficient to fire the gaseous mixture. The size of arc or spark that will occur when an electric circuit is opened depends upon a number of things, such as the voltage of the circuit, the amount of current broken, the speed of break, and the character of the circuit. The determination of the exact influence of each of these factors is an interesting problem. For all practicable purposes, however, it is safest to assume that all sparks which occur around such apparatus and circuits as are used for power and light in a mine are capable of igniting gas. Although this assumption may not be correct at all times, the continually varying conditions surrounding such equipment make a contrary assumption unsafe. For instance, a motor that is so well designed and so adapted to its load that the commutating sparks are too minute to ignite gas may, in starting, develop dangerous sparks.

The ignition of gas by incandescent lamps is now being investigated by the American Bureau of Mines. A large number of lamps of various sizes are being broken in different ways while surrounded by a highly explosive mixture of gas and air. The results so far obtained show that certain sizes of lamps when broken in the presence of gas will ignite it, and that in the action of the lamps there is a difference which depends upon the size of the filament, the larger filaments being more likely to ignite gas than the smaller ones.

The study of the ignition of coal dust by electric arcs and electric flashes has been undertaken to some extent. The results of the experiments indicate that electric flashes can ignite coal dust suspended in the atmosphere.

The conditions surrounding electrical apparatus in mines are more severe and less constant than those surrounding similar installations above ground; there are more trouble-causing factors than are found upon the surface. Falls of roof sufficient to wreck feeder systems are not uncommon. Dampness, dust, and acid water in sufficient quantities to be detrimental to insulation are present in many mines. Some or all of these conditions must usually be considered in selecting mine electrical equipment. Apparatus that might operate satisfactorily in the absence of these elements will fail when they are present. The space available for installing and operating underground electrical equipment is usually limited, thus increasing the chance for accidental contact with the live part of the system. Another factor that has more influence than is usually recognised is the lack of light. Not only has this condition a direct bearing upon accidental contact with electrical apparatus, but it also has an undesirable indirect influence because of the difficulties which it places in the way of properly installing and inspecting the equipment.

As compared with electrical installations on the surface, those underground are temporary in character. Circuits and machines are put in place with the certain knowledge that sooner or later they must be removed and installed elsewhere. This fact undoubtedly has an undesirable influence upon the quality of work performed. For economic reasons it is not practicable to resort to methods of installation that would be followed if the work were to be permanent. Although elaborate methods of installation may in time pay for themselves in low cost of maintenance, such methods are not economical if the equipment is to be moved frequently. Obviously, an installation investment in excess of the amount necessary for satisfactory operation during the period of service is an entire loss. If the period of service is to be short, there is a natural tendency to limit the cost of installation. Whether such curtailment is wise depends so largely upon circumstances that no general statement can be made. However, undue reduc-

tion in installation expenditures not only reduces the factor of safety at one point, but also lowers the general standard of workmanship throughout the mine.

The problem of safeguarding electrical mine equipment is not a simple one. As previously stated, scanty light, limited space, and the presence of dust and dampness are underground conditions that are favourable to the occurrence of electrical accidents. The influence of the first of these may be eliminated by providing lights at particularly dangerous places, such as partings and cross-overs. If electric wires are a source of danger at such places they can be made a source of light also. Although it may be impracticable to eliminate entirely the effect of limited space, this condition may be counteracted by the erection of guards about apparatus. Dust and dampness are elements that can hardly be separated from the operation of a mine; in fact, the presence of dampness is often desirable to offset the effect of dust. It is possible, however, to provide apparatus so designed and installed as to resist the action of dust and dampness, and the more generous the factor of safety included in such design and installation the greater will be the resistance.

The problem of safeguarding may be divested of some of its vagueness and put in concrete form by considering that if the electric current can be kept where it belongs—in the conductors designed to carry it—it cannot give shocks, start fires, or ignite gas, dust, or explosives. Electricity becomes actively dangerous only when it breaks away from its proper channels in stray currents or as sparks and arcs. As far as stray currents are concerned the confinement of electricity in its proper place is primarily a question of insulation, a term that includes the covering of conductors, the insulators upon which they are supported, and the insulating material used in motors and accessory equipment. Against insulating coverings for conductors is brought the argument that such coverings deteriorate rapidly and are an added element of danger because they give false impressions of safety. The truth of this argument depends upon the kind of insulation and the conditions of service, and cannot be regarded as universally applicable.

In order to ensure a high factor of safety in the insulation of motors and other electrical machines, they must be carefully selected with a view to the service which they are to perform. They must then be protected from moisture and dust unless such protection is inherent in their design. Care in this respect will be rewarded not only by increased safety, but also by decreased cost of upkeep. The maintenance cost of enclosed motors operated in damp and dusty places should be less than for open motors operated under the same conditions if both types of machines are properly designed, constructed, and rated.

It must be admitted that the electric current cannot be kept where it belongs in the sense of eliminating entirely such sparks and arcs as occur at fuses, circuit-breakers, air-break switches, starting rheostats, and the commutators of direct-current machines. In this connection the factor of safety must be applied by arranging to confine the outbursts of current to a limited area unoccupied by anything which may be affected by heat or fire.

Assuming that in the selection and installation of electric equipment care has been exercised to ensure the proper confinement of the current, the factor of safety may be increased by earthing the dead metallic parts of apparatus, by providing means for insulating the bodies of those who work upon such apparatus, and by barring from the vicinity of the current such elements as are explosive or combustible.

It is as important to maintain a high factor of safety as to obtain it in the first place, and this requisite calls for careful and frequent inspection by the mine electrician, whose responsibilities can scarcely be over-rated. The supervision of the electrical equipment of a mine is a task that requires unusual ability, sound judgment, and experience of a peculiar sort. To select suitable apparatus, to instal it properly and economically, and to maintain it free from interruption of service at a minimum cost demands much ability. When the requirements of safety are added to the list of duties the responsibility is not lessened. The establishment and maintenance of a high factor of safety rests as much with the man who has direct charge of the electrical equipment as with anyone.

MATHEMATICS IN ENGINEERING.

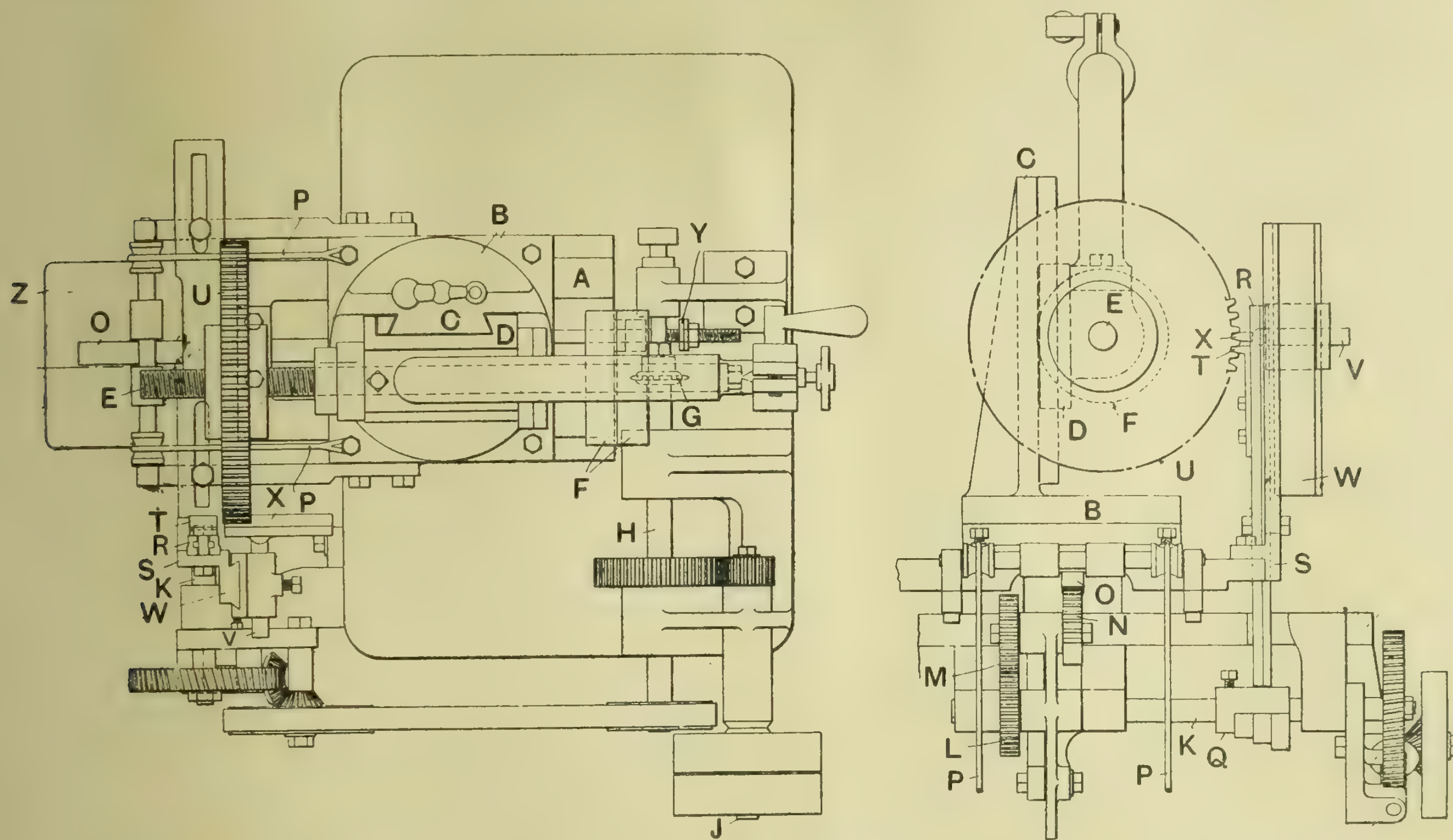
SIR W. H. WHITE, formerly Director of Naval Construction, in the course of a lecture delivered before the International Congress of Mathematicians at Cambridge on "The Place of Mathematics in Engineering Practice," remarked how essential it was that an adequate knowledge of mathematics must be acquired by every practical engineer. Differences of opinion had always been rife as to the best methods of teaching mathematics to engineering students, but he noted that few engineers engaged in practical work had opportunities of using their mathematical tools. No branch of engineering had benefited more from the knowledge of mathematics than naval architecture, and it was a noteworthy fact that Cambridge University had found nearly all the men who had been responsible for the construction of the British Navy during the past 50 years. Although screw propellers had been in use for over 70 years, he had to confess that they still knew little about them, and mathematicians had not helped them a bit. Sir William described at some length the experiments with screw propellers which the Department of Naval Construction carried out some years ago when called upon to design a ship of 23 knots, a speed which at that time had not been approached, and he had to confess that the results were not satisfactory. Mathematicians seeking fresh fields to conquer might profitably study the utterances of practising engineers of repute, and particularly the group which govern the efficiency of screw propellers when applied to steamships. It was no exaggeration to say that at the present time there exists no mathematical theory which has any considerable influence on the design of the screw propeller and the determination of the form, area, and pitch. He made an open confession of the lack of complete knowlege of mathematics on the part of engineers, who wanted every aid that science could give them. They were always ready to gratefully acknowledge very valuable help given by mathematicians, and he felt that this expression would be endorsed by all members of the engineering profession.

EGLIN'S GEAR-CUTTING MACHINE.

A MACHINE for cutting spur gears, the invention of Messrs. W. P. Eglin, Ltd., Globe Works, Sowerby Bridge, is shown in the accompanying cuts, Fig. 1 being a plan view of the machine, Fig. 2 an end view, and Fig. 3 a partial longitudinal section. On the table is mounted a carriage A, on which is movable longitudinally a slide B forming part of a vertical pillar C. In a bearing on a slide D adjustable vertically on the standard C is mounted a spindle E on which the blank F to be cut is secured. The cutter G is mounted on a spindle H driven by gears from a shaft J. A pulley on the shaft H transmits motion through a belt, pulley, and gears to a shaft K. Fast on this shaft is a pinion L which meshes with a pinion M on a stud carried by the arm of a lever loosely mounted on the shaft K and having its other arm secured to a fixed bracket, as shown in Fig. 3. Fast on the same spindle as the pinion M is a partially toothed pinion N adapted to mesh with the teeth of a rack O secured to the slide B. The pinion N revolves in the direction of the arrow, Fig. 3, and so long as the teeth of the pinion are in mesh with the teeth of the rack O the rack, and consequently the slide B, will be moved in a direction to carry the blank towards the cutter G. A weight Z connected by chains P to the slide B acts to draw the slide to the left (Fig. 1), that is to say, in a direction to move the blank back clear of the cutter when in the rotation of the pinion N, the last tooth thereon moves clear of the rack O. The number of teeth in the pinion N, and the consequent distance the rack is moved at each rotation thereof is regulated according to the width of the face of the blank or blanks being cut. The position of the pinion N is capable of adjustment. Fast on the shaft K is a cam Q having three steps or lifts of varying heights, one or other of which according to the longitudinal adjustment of the cam on the shaft is adapted to engage and raise, at the proper time, a slide R movable vertically in a guide. Secured on the slide R is a finger T adapted to engage in a tooth space of a dividing wheel U fast on the blank spindle E and according to the particular step of the cam Q by which the slide R is engaged, to rotate the dividing wheel

through one, two, or three teeth as may be required to give the necessary circular feed to the blank prior to the commencement of each fresh cutting movement.

Carried by a spindle V secured in a slide adjustable vertically on a fixed guide W is a flat plate or member X extending longitudinally of the direction of the sliding motion of the dividing wheel U. This member X is adapted, as the slide B moves the blank towards the cutter, and before the dividing wheel U has moved longitudinally clear of the finger T, to engage in a tooth space of the dividing wheel and to accurately position same. The engagement of the member X with the wheel U is timed to take place before the blank reaches the cutter so that in the event of the finger T having failed to move the wheel U to the exact required position, the error will be corrected by the fixed member X. The wheel U slides on the member X during the whole of the time cutting is taking place, consequently the blank is held or locked in the correct position from end to end of its movement past the cutter and absolute accuracy in cutting is assured. The return movement of the slide B to carry the blank back to starting position on completion of each cut is limited by means of an adjustable stop Y.



FIGS. 1 AND 2.—EGLIN'S GEAR-CUTTING MACHINE.

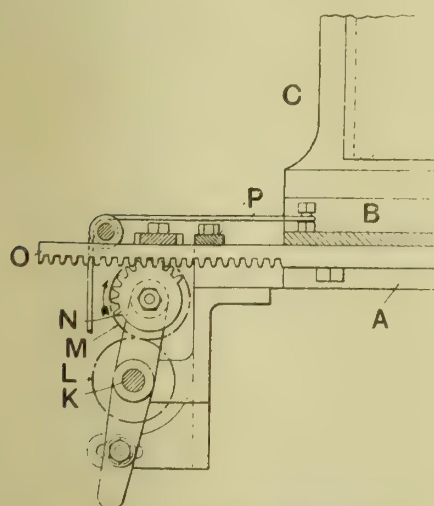


FIG. 3.—EGLIN'S GEAR-CUTTING MACHINE.

The action of the machine, assuming that the blank is approaching completion of a cut, is as follows: The partially toothed pinion N is set so that its last tooth leaves the rack O as soon as the blank has moved past the cutter. Immediately the rack is freed by the pinion N, the weight Z on the chains P which has been raised during the forward movement of the blank, causes the slide to be drawn back and the blank to be carried back to its starting position, determined by the stop Y. The backward movement of the slide has caused the dividing wheel U to slide off the positioning member X and on to the dividing finger T. The cam Q now lifts the slide R and causes the finger T to give the requisite rotation to the dividing wheel and consequently to the blank. By the time the cam has effected this raising of the finger T the pinion N again begins to mesh with the rack and to cause the slide to move towards the cutter, but before the blank has been moved far enough to reach the cutter and before the dividing wheel has moved far enough to leave the finger T, the wheel is engaged by the positioning member X along which it slides and by which it is locked throughout the cutting movement of the blank. The cycle of operations above set forth is automatically repeated until the whole periphery of the blank has been cut.

Explosion in a Gasometer.—An explosion occurred in the interior of a gasometer, in which three men were working, at the gasworks of the Mossley Corporation on the 29th ult. One man was killed outright and two others seriously injured. The latter were rescued by the foreman at great personal risk. The gasometer was capable of holding 500,000 cub. ft. of gas and was 100ft. diam. The gas was cleared from the structure two months ago, and it had since been elevated by air. A number of men employed by Messrs. Ashmore, Benson, Pease, & Co., of Stockton-on-Tees, were engaged in the interior on repairs. On the afternoon of the explosion the gasometer was at a very low level when three men entered it to continue their work. One of the men struck a match to light a candle by which to work. By some means at present unexplained gas had accumulated in the chamber and there was at once a violent explosion, with the result that the gasholder was lifted to a height of 20ft. and the supporting pillars broken.

THE BRITISH ASSOCIATION.

THE 82nd annual meeting of the British Association for the Advancement of Science was opened last week at Dundee, under the presidency of Prof. E. A. Schäfer. The engineering section was presided over by Prof. Archibald Barr, whose address was reproduced in our last issue (see p. 295 ante). This was followed by a number of interesting papers, abstracts of which are presented below.

Experiments on "Suction" or Interaction Between Passing Vessels. — In view of the general lack of experimental data as to the magnitude of the mutual forces involved in the cases of interaction between two vessels moving in parallel paths in close proximity, and as to their effective range of action, the authors (Prof. A. H. Gibson, D.Sc., and Mr. J. Hannay Thompson, M.Sc.,M.Inst.C.E.), decided to carry out a series of experiments to investigate these points on boats of sufficiently large size to enable the results to be applied with some confidence to sea-going vessels. The vessels used were the steam yacht "Princess Louise" and a motor-boat, each being propelled by a single screw. Their details are as follows:—

Vessel.	Length between Per-p'ndiculars	Beam.	Draught.	Displacement.	Rudder Area.
	ft. in.	ft. in.			
"Princess Louise"	88 6	13 0	6ft. forward 7ft. aft		—
Motor-boat	29 6	6 9	2ft. 3in.	–	100 sq. in.

Two sets of experiments were carried out. In the first the helm of the motor-boat was lashed amidships, with the vessels on parallel paths, and its behaviour was noted when at different lateral distances, and when the boats were moving at different absolute and relative speeds. Its position relative to the "Princess Louise" was determined by angular measurements taken from the latter vessel at intervals of 15 seconds. Pressures at a series of corresponding points on the two sides of the motor-boat were measured at the same instants, with a view to determining the lateral forces involved. The second series of experiments was devoted to a determination of the helm angle necessary to maintain the course of the motor-boat when in different positions relative to the larger vessel. Owing to possible collision risks the maximum speed was limited to six knots, which, in the case of the "Princess Louise," corresponds to 18 knots in a vessel of the size of the "Olympic." The results showed that with both vessels moving at about this speed with helms amidships the smaller vessel was drawn into collision from any lateral distance less than 100ft. (three and a half lengths of the smaller vessel). The precise behaviour depended largely on the relative and absolute speeds of the vessels and on their initial distance apart and initial relative position. These points were discussed in the paper, as was the question of the helm angle required to prevent collision. The authors were of opinion that the experiments proved conclusively that the forces involved during interaction were much greater than had been generally realised hitherto, while they were particularly impressed by the rapidity with which collision usually followed the first sign of any interaction.

The Experimental Determination of the Stresses in Springs.— This subject was dealt with by Prof. E. G. Coker, M.A., who said that the chief difficulties in determining the state of stress in a body usually arose from the great variations of stress intensity which occurred owing to its complicated shape and the loading; and further, in the case of springs where plates were built up into a matrix, the rubbing friction between the surfaces was usually considerable enough to render the assumptions of perfect elasticity of the whole body somewhat unreliable for purposes of calculation, although each plate might be regarded as fulfilling the elastic conditions perfectly. Methods of experiment were described by optical and electrical methods of general application to stress problems. In the first method, models of springs were constructed of transparent materials for which it was shown that the stress distribution was very similar to that in steel. These models permitted of determinations of the difference of principal stresses at any point, and an important result was that the optical effect of a pure shear was proportional to twice the numerical value of one of the principal stresses. Examples of plate springs and flat-coiled springs were considered in detail, and the general distribution of stress illustrated by diagrams and natural-colour photographs of springs viewed in polarised light. The second method depended on the fact that steel and other metals when subjected to stress within the elastic limit experienced a change of temperature—a diminution for tension stress and an increase for compression stress—proportional to the stress. The effect at any point, therefore, was due to the sum of the principal stresses, and in cases of pure shear the effect was zero—a noteworthy difference from the first method. Examples of tension, compression, bending, and shear experiments were described showing the applications of the electrical method. The paper described some attempts to utilise the difference in the electrical condition of stressed and unstressed metals for determining the stresses in materials.

The Acceleration of a Motor-car.—In the first part of this paper, by Mr. H. E. Wimperis, M.A., a simple graphical method is given of predicting from its design the acceleration and hill-climbing ability of a motor-car. In the first place, a torque-speed curve was constructed; from this was deduced an acceleration-speed curve; and from this in turn was derived the acceleration-time graph. In working out these curves a 15 h.p. car was taken as typical. The next part of the paper contained an account of the methods in use for the experimental measurement of the acceleration of a motor-car. The various advantages and disadvantages of these methods were discussed. The author then gave the actual acceleration curves for the above-mentioned car as obtained by the use of a recording accelerometer. Two cases were taken (*a*) when starting as in a race, and (*b*) when starting as in ordinary running. The predicted and actual curves were compared and the differences analysed. The author showed that the choking of the carburetter caused a material loss of acceleration on starting. The paper concluded with a reference to the considerations which influence what may be termed "ideal acceleration," and pointed out that this ideal was incapable of attainment with cars as at present constructed.

Exposure Tests of Light Aluminium Alloys.—During the past 11 years reports have been presented by Prof. Ernest Wilson to the British Association at fairly regular intervals. The tests showed that alloying commercial aluminium with copper, unaccompanied by iron, nickel, or manganese, was not satisfactory. A 2·6 per cent. copper alloy had completely deteriorated in 10 years and increased its electrical resistance 25 per cent. "Duralumin" was a copper-manganese alloy of aluminium with the addition of about 0·5 per cent. magnesium. During the last year a specimen had increased its electrical resistance 5·15 per cent. It would be interesting to know if this was due to the comparatively large percentage of copper (3·5 to 5·5) which this alloy was stated to contain, or if the percentage of manganese (0·5 to 0·8) was too low. This alloy had attracted attention in that a breaking load as high as 90,000lbs. could be obtained, if desired, according to treatment. Its specific electrical resistance at 15° C. was about twice that of commercial aluminium. A specimen of high-conductivity copper wire had increased its electrical resistance 1·2 per cent. in one year.

The Behaviour of Ductile Material during Torsional Straining.— In this paper, by Mr. C. E. Larard, the author said the exact recorded limit of "proportionality between strain and stress" might depend on the instrument used and the degree of fineness to which it was possible to indicate the strain. The yield period in torsion and the yield load was dependent on the time rate of loading. If the test be made very slowly there was no sudden plastic yield experienced similar to that obtained in the case where a test was carried out moderately quickly. In fact the stress-strain curve was smooth and continuous. The approximate laws of flow of ductile during twisting at a uniform angular velocity might be stated as follows: (*a*) The rate of increase of the torque with respect to time varied inversely as the time and therefore inversely as the strain or angle of twist. (*b*) The acceleration, which decreased, or as it may be called the deceleration of the torque with respect to time varied inversely as the square of the time or inversely as the square of the angle of torsion. (*c*) The relationship between torque and time, and therefore between torque and twist, followed the compound interest law. Two theories had been advanced to explain the method of fracturing of a

specimen. (1) The author's theory, which might be stated: When the maximum torque was reached shearing took place over an annulus near the periphery, the shearing extending from annulus to annulus of decreasing mean radius and under a diminishing value of the torque until owing to the irregular form of the sheared area setting up a wedging action a more or less central core of the material was fractured by tension. (2) A theory advanced by Dr. Wm. Garnett, in which he suggested that the outside layers being in helical tension and the inside layers in compression, resulting in one cylindrical layer being in a state of pure shear so that the first part of the failure was due to tension of the outside annulus, while the second part and the flying apart of the two pieces of the specimen was due to sudden release in compression. Lantern slides and kinematograph illustrations were given for cylindrical, hollow, square, and rectangular sections, as well as for the machine representing its operations. The projections, enormously enlarged, were made in a small fraction of the time required for the tests; so that the behaviour of the material was readily demonstrated. In the case of the wrought iron, the defects of the metal were made manifest, while the flow had the appearance of a turgid stream in motion.

Alternating Load Tests.—This paper, by Mr. Bernard P. Haigh, B.Sc., dealt with the testing of wire specimens under pulsating loads, the pull being applied in a sine-wave by a machine comprising an electromagnet supplied with alternating current. The pull of such a magnet varied between zero and a maximum in a sine-wave with twice the frequency of the alternating current supplied, and the maximum pull was proportional to $(E \div C)^2$, where E and C were respectively the voltage and frequency of the current. The wire specimen was attached at its lower end to an armature which vibrated above the pole face of the magnet, the magnetic circuit being arranged so as to give as light an armature as practicable. The conditions necessary to ensure that the pull was independent of the range of vibration were discussed, and also the means by which the forces absorbed in accelerating the mass of the armature in its harmonic motion were compensated. The vibrating armature was carried on springs adjusted to such a stiffness that the force exerted under any given deflection was equal to that required for the acceleration of the mass of the armature in that amplitude at the particular frequency of the test required. In the instrument exhibited the springs were arranged to compensate at frequencies from 35 up to 120 extensions per second, and were adjusted by an experimental method employing "resonance." The springs were also arranged to hold the armature in position, and as no guides were employed it was unnecessary to make any allowance for friction. The value of the pull was calculated from the readings of the frequency and the voltage induced in a special measuring coil, which was wound close to the armature so that the flux measured was independent of leakage. The "factor" of the instrument was determined experimentally by a method in which a standardised spring was substituted in place of the specimen, and a heavy mass was attached to the armature to reduce the amplitude of vibration. The maximum value of the magnetic pull was double that of the mean value which was thus determined. It was shown that the influence on the wave of pull of higher harmonics in the wave of electromotive force was small, as only the fifth and seventh harmonics were active. A search coil was provided in the instrument for checking their values by means of an oscillograph. Particulars were given of tests carried out with ductile and hard-drawn steel wires. From these it appears that specimens of a 0·47 per cent. carbon steel broke when tested under pulsating load, with about 85 per cent. of their breaking load under steady loads. A ductile low-carbon steel, on the other hand, broke with only 65 per cent. of the steady breaking load, *i.e.*, at a load close to the yield point. The extension of this material under pulsating load (20 per cent.) was very close to that obtained with steady load.

The Féry Bomb Calorimeter.—This paper, by Mr. Robert S. Whipple, dealt with the Féry bomb calorimeter. This form of calorimeter was, he said, now frequently employed for the determination of the calorific value of coal, because the combustion of the coal was more complete than in those calorimeters in which the oxygen was admitted at atmospheric pressure or at a pressure slightly above atmosphere. The instrument designed by Prof. C. Féry, of the Ecole de Physique et de Chimie, Paris, was of the bomb type, being in general design somewhat similar to the well-known Mahler instrument, but greatly simplified in its details. The bomb consisted of a light iron vessel weighing about 1 kilo, and had a capacity of about 250 c.c. supported in the centre of a brass vessel by two discs of constantan (an alloy of copper and nickel). As the mass of metal in the bomb was small and no water-jacket was used, the rise in temperature of the bomb due to the combustion of the coal was large, averaging about 20° C. when 0·5 gramme of coal was burnt. It was evident that with such a large temperature rise the measurements need not be made with the same degree of accuracy as in the case of the usual type of bomb calorimeter, in which the temperature rise amounted to only 2° C. or 3° C. for the same quantity of coal. The temperature rise was measured by the thermo-electric force generated by the constantan discs and the iron bomb, the surrounding envelope acting as the cold junction of the thermo-couples. These couples gave an electromotive force of 40 micro-volts per degree C., and gave on a pointer galvanometer a deflection of 60 mm. for a rise of 20° C. It was thus possible to estimate the temperature rise of the bomb to at least $\frac{1}{5}$° C. or to $\frac{1}{300}$ of the total rise in temperature. The loss of heat from the bomb was due to three causes: (1) conduction along the constantan discs; (2) convection currents in the air space surrounding the bomb; and (3) radiation from the walls of the bomb. The effect of the loss by conduction was only to lower the maximum temperature obtainable as compared with what it would have been if the supporting discs were non-conductors. The losses due to convection and radiation were negligible as compared to those due to conduction. The coal under examination was placed on a small tray in the bomb, the latter being filled with oxygen at about 200lbs. pressure. The coal was fired electrically, and the maximum temperature rise on the galvanometer took place about $1\frac{1}{2}$ minutes after ignition. Experiments showed that the gas pressure could be varied from 150lbs. to 250lbs., and the weight of coal burnt from 0·2 to 0·7 gramme, without any difference in the results obtained. The instrument was standardised by burning either sugar, carbon, or standardised coal briquets, the calorific values of which were known. The instrument was easy to operate, and gave consistent results.

The Ignition of Gaseous Mixtures by Momentary Electric Arcs.—This paper, by Prof. W. M. Thornton, D.Sc., gives the results of an investigation to ascertain the least currents, direct and alternating, required to ignite gaseous mixtures at different voltages and frequencies. The lower and upper limits of mixture within which ignition was possible were found to be 4·25 and 14 per cent. for firedamp in air, 6 and 40 per cent. for coal gas. There was a well-defined maximum of sensitiveness to ignition at 7 per cent. in the former, 8·5 per cent. in the latter. With direct voltage the least igniting current was approximately proportional to the reciprocal of the voltage; with alternating voltage the frequency was of more importance, and the current remained constant over a long range of voltage, being higher for methane than for coal gas. The energy of spark which would just ignite the most sensitive mixtures was about 0·10 joule, corresponding to the combustion of 37 c.c. of an 11 per cent. mixture of coal gas. Single sparks therefore gave relatively poor ignition. It would appear from the results that when alternating current was used for signalling or where there was no continuous sparking at a contact, the risk from electrical signalling in coal mines was extremely small. Where there was sparking as at a vibrating contact the bells must be enclosed in flame-proof cases, or be situated in places which could not be reached by firedamp in mixtures approaching 4 per cent.

Personal.—Mr. George Thomas Beilby, F.R.S., LL.D., has been appointed a member of the Royal Commission on Oil Fuel, in succession to Mr. H. Owen Jones, deceased. Mr. Beilby is a prominent man of science, who has made a special study of fuel economy and smoke prevention, and has invented processes which are in use in several departments of industry. He was President of the Institute of Chemistry in 1909, and is chairman of the Glasgow and West of Scotland Technical College. He was born in Edinburgh in 1850, and educated at Edinburgh University.

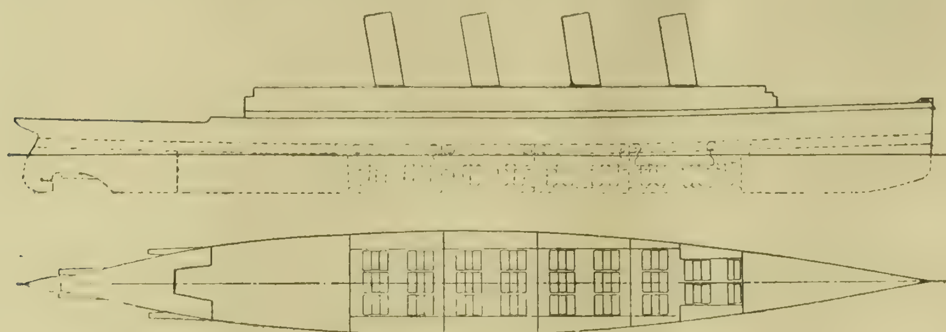
BOILER ECONOMICS AND THE USE OF HIGH GAS SPEEDS.*

BY J. T. NICOLSON.

(Concluded from page 306.)

PART VIII.—APPLICATIONS TO PRACTICE.

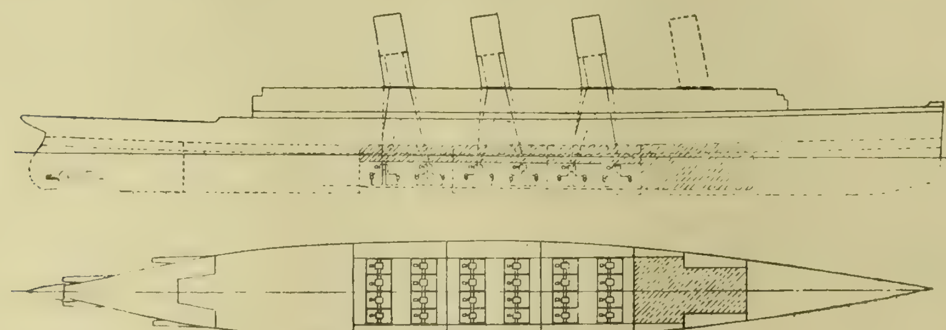
IT ought to be pointed out that in compiling these competitive figures nothing has been allowed for the annual rental value of the floor space saved by the adoption of high-speed boiler plant. This is a most important item in the case of power stations in crowded centres of population. In many cases the mere feasibility of installing the steam generating plant at all turns upon the possibility of economising space in the boiler room. In the author's system less space is occupied than with any other; even the express boilers used on destroyers not being excepted. The author, therefore, proposes now to conclude this rather lengthy paper by giving two examples of the application of the high-speed boiler to practical examples. The type of boiler is that shown in Fig. 15, and the two instances chosen for illustration are from the mercantile and naval marine respectively.



FIGS. 18 AND 19.—R.M.S. "LUSITANIA."

Application to Mercantile Marine.—The "Lusitania" and "Mauretania." In Figs. 18, 19, and 20, the drawings given of these ships in "Engineering," Plate XXXIV., of August 2nd, 1907 (*see* also Plate CII. of November 8th, 1907), have been reproduced as fitted with double-ended return-tube boilers of the usual type; whilst Figs. 21, 22, and 23 show the vessels as fitted with high-speed boilers as proposed by the author. From these figures it can be seen that the proposed design is so much less bulky for a given power than that actually used, that four of the new boilers (each of the same power as the old) can be placed on the same floor space as three of the double-ended boilers of the "Lusitania." Each of the latter boilers has 168 sq. ft. of grate surface (21 sq. ft. per furnace), and 6,393 sq. ft. of heating surface. There are 24 altogether to develop 68,000 i.h.p., so that each boiler develops $\frac{68,000}{24} = 2,840$ i.h.p. An indicated horse-power is developed by 1·45lbs. of coal or 14·5lbs. of steam per hour. Thus the coal burnt per square foot of grate is

$$\frac{68,000 \times 1{\cdot}45}{24 \times 168} = 24{\cdot}4\text{lbs. per hour};$$



FIGS. 21 AND 22. R.M.S. "LUSITANIA."

whilst the evaporation per square foot of heating surface is

$$\frac{68,000 \times 14{\cdot}5}{24 \times 6,593} = 6{\cdot}23\text{lbs. per hour}.$$

The high-speed boilers designed to replace them are also double-ended and placed back to back, with one turbo-fan of 250 b.h.p., to provide a draught of 24in. water gauge, placed above and between them. Each such double-ended boiler has two grate surfaces each of 84 sq. ft. area, or 168 sq. ft. for the two, so that it will have the same grate area as one of the 17ft. 6in. diam. by 22ft. long boilers of the Cunard ships. The plans, Figs. 21 to 23, show clearly how six rows of four boilers per row take up exactly the

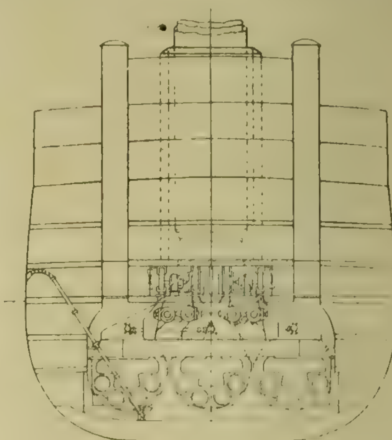


FIG. 20.

same floor space as six rows of three boilers per row in the old design. Thus the whole of the stokehold and boiler space forward of frame No. 197 (*vide* "Engineering," August 2nd, 1907, Plate No. XXXIV., or November 8th, 1907, Plate CII.) can be saved and used for cargo purposes; for those 24 boilers of the new type can easily develop the 68,000 i.h.p. required.

Nor is this all. In the elevation, Fig. 21, it will be observed that the new boilers, along with all fan equipment, can easily be got into a height less than that of the present boilers alone, so that a strip of space (about 12ft. high by 57ft. wide and 250ft. long), where the present fans, &c., are stowed, is also made available along the whole length of the boiler hold. The space saved is as follows:—

Forward of frame 197.

Width (feet).		Length (feet).		Height (feet).		
57	×	47½	×	30	=	81,200 cub. ft.
40	×	52	×	30	=	62,300 cub. ft.

Strip above boilers (between main and lower deck).

50 × 283 × 8 = 113,000 cub. ft.

Total = 256,500 cub. ft.

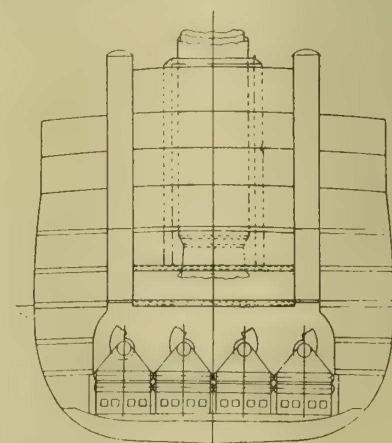


FIG. 23.

Allowing the usual figure of 40 cub. ft. to the ton, this saving amounts to 6,400 tons of extra cargo space.

Estimating the boiler-hold displacement under present conditions at 17,000 tons, the above saving of space amounts to over 37 per cent. thereof. The author is not able to say

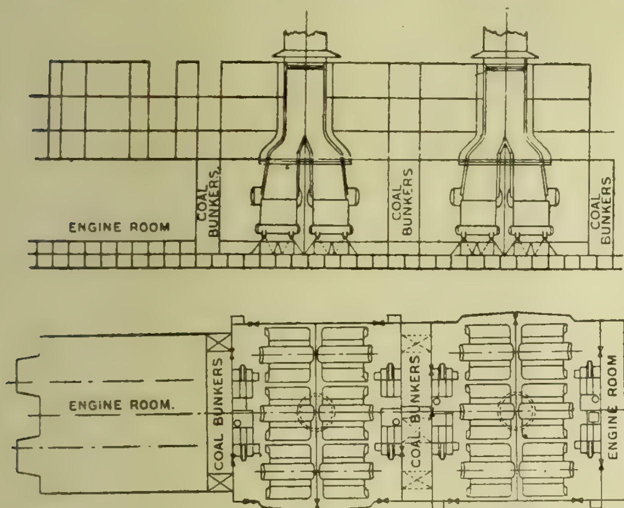
* Paper read before the Institution of Engineers and Shipbuilders of Scotland.

what the annual value to the shipowner of one ton of cargo space is.

As to economy, a net evaporation of 11lbs. of cold water can easily be guaranteed per pound of the kind of coal burnt on a Cunarder with such a low rate of firing as 25lbs. per square foot of grate per hour.

Application to Ships of War.

Chilian battle-ship "Libertad" (*vide* "Engineering," January 15th, 1904). This ship of 18,000 tons displacement was fitted with 12 Yarrow boilers, each of 1,200 h.p., the speed of the ship being 20 knots. As shown by Figs. 24 to



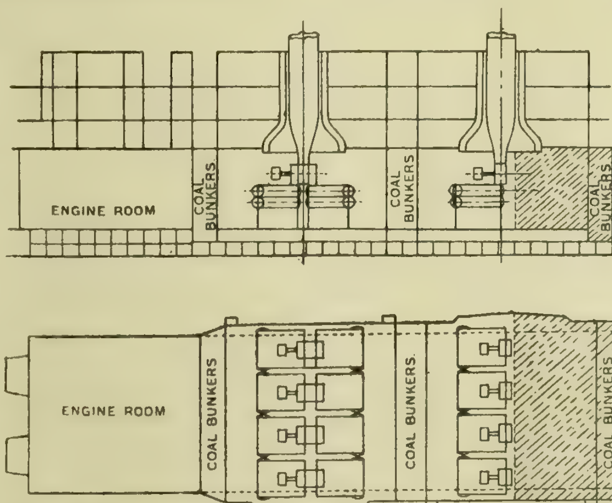
FIGS. 24, 25, AND 26.—CHILIAN BATTLE-SHIP "LIBERTAD." BOILER HOLD 105FT. LONG, 46FT. WIDE, 20FT. HIGH.

29, three rows of four boilers, each of the high-speed type, with turbo-fans, occupy the same floor space as three rows of three boilers each of the Yarrow type, the high-speed boilers being each capable of more than the 1,200 h.p. for which the Yarrow boilers were designed. A boiler-hold displacement of (25ft. long by 45ft. wide by 20ft. high) 22,500 cub. ft. or $\frac{22,500}{40} = 565$ tons is thus saved and made available, either for an additional 33 per cent. of boiler power (thereby increasing the possible speed to about 22 knots); or for an additional 685 tons of coal bunker capacity. The radius of action would in the latter case be increased, at 20 knots, from 3,800 to 5,100 miles.

(N.B.—As the high-speed boilers weigh only 20 tons against the 30 tons of the Yarrow units, there is an additional saving of 120 tons on this account, making 565 and 120 = 685 tons in all.)

The advantages claimed for the high-speed boiler for ships of war may be concisely enumerated as follows:—

(1) Saving of boiler-hold space of 30 per cent.
(2) Saving in boiler weights of 30 per cent.
(3) Economy of coal consumption of at least 5 per cent.
(4) No flaming at the funnels even at full power.
(5) No smoke.
(6) Funnels may be of any (small) height sufficient to carry gases over bridges, and need only have 60 per cent. of the present area.
(7) Steam may be got up from cold in 15 minutes, provided stand-by steam is available for the fans.
(8) Great handiness for changing power by regulation of fan speed.
(9) No closed stokeholds or closed ashpits.



FIGS. 27, 28, AND 29.—CHILIAN BATTLE-SHIP "LIBERTAD." BOILER HOLD 105FT. LONG, 45FT. WIDE, 20FT. HIGH.

APPENDIX I.

Meaning of Symbols used in this Paper.

Q = calorific value (higher value) of 1lb. of coal, Th.U.'s per lb.

Q_0 = heat generated in fire, Th.U.'s per lb.

F = coal fired per square foot of grate per hour, lbs.

G = area of grate, square feet.

A = air supplied per lb. of coal, lbs.

k_p = specific heat of products of combustion.

σ = Thermal capacity of products per lb. of coal, Th.U.'s.

$\sigma = k_p(A + 1)$.

t_3 = entering feed temperature = 60° Fah.

$t_2 = t$, temperature corresponding to steam pressure.

T_0 = fire temperature (°Fah.); τ_0 = fire temperature °Fah. absolute.

T_1 = temperature of gases entering evaporator.

T_2 = temperature of gases leaving evaporator (entering economiser).

T_3 = temperature of gases leaving economiser.

θ = temperature (mean of fire and water sides) of metal of heating surface at any point.

ρ_1 = density of gases, lbs. per cub. ft.

ρ_2 = density of water, lbs. per cub. ft.

u_1 = speed of gases, foot-seconds.

u_2 = speed of water circulation, foot-seconds.

w_1 = weight of gas from one square foot of fire (lbs. per second).

w_2 = weight of water evaporated per second per square foot of grate

a_1 = cross-sectional area of flue per square foot of grate (square feet).

$\rho_1 u_1 = w_1/a_1 = M_1$ = "mass-flow" of gas, lbs. per second per square foot of flue section.

$\rho_2 u_2 = w_2/a_2 = M_2$ = "mass-flow" of water, lbs. per second per square foot of feed channel.

e = total evaporation per lb. of coal, lb. from t_3 at t_2.

e_1 = radiation evaporation per lb. of coal, lb. from t_3 at t_2.

e_2 = convection evaporation per lb. of coal, lb. from t_3 at t_2.

$e = e_1 + e_2$.

s_{ec} = heating surface (economiser) per square foot of grate.

s_{ev} = heating surface (evaporator) per square foot of grate.

s = heating surface (total) per square foot of grate.

$c_1 = \frac{3,600}{B_1}$ = coefficient of heat transference on the gas side, Th.U.'s per square foot per hour per ° Fah.

$c_2 = \frac{3,600}{B_2}$ = coefficient of heat transference on the water side, Th.U.'s per square foot per hour per ° Fah.

W_1 = weight of gas flowing through flue or tube, lbs. per hour.

W_2 = weight of water flowing through tube, lbs. per hour.

APPENDIX II.

For the heat transmitted per second through an elementary length dx of a tube (or tubes) of bore d_1, through which gas at temperature T is passing, and around whose outside diameter d_2 water at constant temperature t is flowing, we have the four values:—

$$dH = c_1\rho_1u_1(T-\theta)\pi d_1dx \quad (1)$$
$$= c_2\rho_2u_2(\theta-t)\pi d_2dx \quad (2)$$
$$= -k_1W_1dT \quad (3)$$
$$= Ldw_2 \quad (4)$$

From (1) and (2)

$$\frac{T-\theta}{\theta-t} = \frac{c_2\,\rho_2u_2\,d_2}{c_1\,\rho_1u_1\,d_1} = nR\beta = r \quad (5)$$

$$T-\theta = \frac{r}{1+r}(T-t) \quad (6)$$

From (1) and (3), substituting from (6) for $T-\theta$:

$$c_1\rho_1u_1\frac{r}{1+r}\pi d_1dx = -k_1W_1\frac{dT}{T-t}.$$

Now

$$r = \frac{c_2}{c_1}R\beta \quad \therefore \frac{r}{1+r} = \frac{c_2R\beta}{c_1+c_2R\beta};$$

also

$$\rho_1u_1 = \frac{w_1}{a_1} \text{ and } W_1 = 3{,}600w_1;$$

$$\therefore \quad \frac{c_1c_2R\beta}{c_1+c_2R\beta}\cdot\frac{1}{3{,}600k_1}\cdot\frac{\pi d_1}{a_1}dx = -\frac{dT}{T-t}. \quad (7)$$

This can now be integrated, as t is constant.

$$\frac{c_1c_2R\beta}{3{,}600k_1(c_1+c_2R\beta)}\frac{l}{m_1} = \log_e\frac{T_1-t}{T_2-t}$$

or

$$\frac{s_{ev}}{a_{ev}} = \frac{l_{ev}}{m_{ev}} = \frac{3{,}600k_1(c_1+c_2R\beta)}{c_1c_2R\beta}\log_e\frac{T_1-t}{T_2-t}$$

which is equation (8) in the text.

APPENDIX III.

The heat dH transferred in the steady state through an elementary length of tube, Fig. 30, is:—

$$dH = c_1\rho_1u_1(T-\theta)\pi d_1dx \quad (1)$$
$$= c_2\rho_2u_2(\theta-t)\pi d_2dx \quad (2)$$
$$= -k_1W_1dT \quad (3)$$
$$= -k_2W_2dt \quad (4)$$

From (1) and (2)—

$$\frac{T-\theta}{\theta-t} = \frac{c_2\rho_2u_2d_2}{c_1\rho_1u_1d_1} = nR\beta = r \quad (5)$$

Hence:

$$\theta = \frac{1}{1+r}T + \frac{r}{1+r}t \quad (6)$$

$$T-\theta = \frac{r}{1+r}(T-t) \quad (7)$$

and

$$\theta-t = \frac{1}{1+r}(T-t) \quad (8)$$

From (1) and (3) substituting from (7) for $T-\theta$:—

$$\frac{c_1}{3{,}600k_1}\frac{r}{1+r}\frac{\pi d_1}{a_1}dx = -\frac{dT}{T-t} \quad (9)$$

From (3) and (4) denoting

$$\frac{k_2W_2}{k_1W_1} = \frac{T_1-T_2}{t_1-t_2} \text{ by } K \quad (10)$$

we get—

$$t = t_1 - \frac{T_1-T}{K} = t_2 - \frac{T_2-T}{K} \quad (11)$$

and—

$$T-t = \frac{K-1}{K}\left[T-\frac{Kt_1-T_1}{K-1}\right] = \frac{K-1}{K}\left[T-\frac{Kt_2-T_2}{K-1}\right] \quad (12)$$

Substituting in (9) the value for $T-t$ from (12); and denoting the known quantities

$\frac{Kt_1-T_1}{K-1} = \frac{Kt_2-T_2}{K-1}$ by b: we get $\left[\text{with } m_1 = \frac{a_1}{\pi d_1}\right]$:—

$$\frac{c_1}{3{,}600k_1}\frac{r}{1+r}\frac{dx}{m_1} = -\frac{K}{K-1}\frac{dT}{T-b}.$$

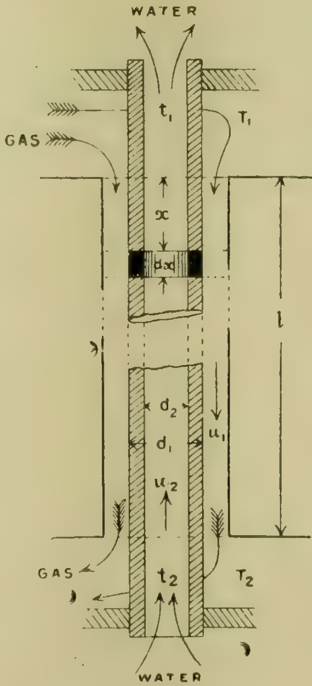


FIG. 30.

This can now be integrated, since b does not depend on the variable T; and thus we obtain:—

$$\frac{c_1(K-1)}{3{,}600k_1K}\frac{r}{1+r}\frac{l}{m_1} = \log_e\frac{T_1-b}{T_2-b} \quad (13)$$

APPENDIX V.—A PORTION OF MR. LONGRIDGE'S REPORT.

Ref.		Oct. 12	Oct. 13	Oct. 14	Oct. 19	Oct. 20	Oct. 21	Ref.
14*a*	Weight of dried fuel fired per hour .... Lbs.	662·6	665·5	399·5	467·5	724·0	721·0	14*a*
22*b*	Average temperature of gases entering evaporator, T_2 ...... Deg. Fah.	1,252	1,322	1,184	1,138	1,360	1,418	22*b*
22*c*	,, ,, ,, in combustion chamber, T_1 .... ,,	2,162	3,000	2,000	1,945	3,000	3,000	22*c*
23*a*	Heat capacity of gases per lb. dry coal:—Total		3·8835	4·8843	5·0123	3·5426	3·6707	23*a*
56*f*	Velocity of gas entering narrow annular space in boiler ..Feet per second		149	79	96	148	152	56*f*
56*g*	,, ,, leaving narrow annular space in boiler .... ,, ,,		82	57	66	83	89	56*g*
56*h*	,, ,, entering evaporator .... ,, ,,		140	98	114	146	152	56*h*
56*i*	,, ,, leaving evaporator .... ,, ,,		116	73	92	122	128	56*i*
56*j*	,, ,, entering economiser .... ,, ,,		139	83	110	142	153	56*j*
56*k*	,, ,, leaving economiser .... ,, ,,		114	66	87	118	128	56*k*
56*l*	Density of gases entering annular space in boiler ......Lbs. per cubic foot		0·0112	0·0174	0·0163	0·0113	0·0108	56*l*
56*m*	,, ,, leaving annular space in boiler .... ,, ,,		0·0205	0·0195	0·0236	0·0202	0·0195	56*m*
56*n*	,, ,, ,, evaporator .... ,, ,,		0·0249	0·0300	0·0291	0·0244	0·0233	56*n*
56*o*	,, ,, ,, economiser .... ,, ,,		0·0304	0·0397	0·0367	0·0293	0·0279	56*o*

Similarly for the water side we obtain: —

$$\frac{c_2(K-1)}{3{,}600k_2}\,\frac{1}{1+r}\,\frac{l}{m_2}=\log_e\frac{t_1-b}{t_2-b} \quad . \quad . \quad . \quad . \quad (14)$$

$$\left[\text{here } m_2=\frac{a_2}{\pi d_2}\right]$$

But

$$\frac{T_1-b}{T_2-b}=\frac{t_1-b}{t_2-b}=\frac{T_1-t_1}{T_2-t_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

and

$$\frac{r}{1+r}=\frac{c_2R\beta}{c_1+c_2R\beta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

Therefore, substituting in (13) from (15) and (16), we have

$$\frac{K-1}{3{,}600k_1K}\,\frac{c_1c_2R\beta}{c_1+c_2R\beta}\,\frac{l}{m}=\log_e\frac{T_1-t_1}{T_2-t_2};$$

or

$$\frac{s_{ec}}{a_{ec}}=\frac{l_{ec}}{m_{ec}}=\frac{3{,}600k_1K}{K-1}\,\frac{c_1+c_2R\beta}{c_1c_2R\beta}\log_e\frac{T_1-t_1}{T_2-t_2}.$$

The equation (9) as given in the text.

APPENDIX IV.

The formula for the drop of pressure through a boiler tube may, to a first approximation, be written of the same form as if the flow were of water, namely: —

$$h=\frac{P_1-P_2}{\rho}=\frac{4\zeta l}{d}\,\frac{u^2}{2g}$$

Now

$$\rho=\frac{P}{c\tau},\ \therefore \triangle P-P_1-P_2=\frac{P}{c\tau}\frac{4\zeta l}{2g}\frac{l}{d}u^2$$

To obtain

$$\triangle P \text{ in terms of } \rho u=\frac{w}{a}$$

we have

$$\rho u_2=\frac{c\tau}{144p}\left(\frac{w}{a}\right)^2$$

$$\therefore\quad \triangle P=\frac{53\cdot18\tau\zeta}{144^2p\times2g}\left(\frac{w}{a}\right)^2\frac{l}{m}$$

With $\nabla p''=27\cdot7\triangle P$ we obtain the formula (19) in the text.

Coal Consumption of Locomotives.—In the paragraph on page 290 of our last issue the figures throughout refer to coal consumption and not to steam consumption as stated.

Reliability of Electric Locomotives.—During last year 33 electric locomotives were operated on the Pennsylvania Railroad's New York terminal district with a total delay of only 13 minutes attributable to the electric apparatus. The total mileage run by these locomotives was 909,238, and in one case the mileage amounted to 56,000.

Personal. — Mr. Thomas H. Mottram, H.M. Inspector of Mines in the Liverpool and North Wales District, has been appointed by the Secretary of State to the position of divisional inspector of mines of the Yorkshire and North Midlands Division, in succession to the late Mr. W. H. Pickering, who was killed in the Cadeby Colliery explosion. Mr. Mottram will be succeeded in Lancashire by Mr. J. R. R. Wilson, of Leeds.

Another Crane Accident.—An accident occurred on the 5th inst. on the extension of the works of Messrs. Goldsworthy and Sons, emery manufacturers, Manchester, resulting in serious injury to three workmen. It appears that the men, who are employed by a firm of contractors, were working on a scaffolding two storeys high. A crane on the scaffolding was lifting a large iron girder when it suddenly collapsed, and the jib turned completely over. The greater part of the crane fell from the platform on to some scaffolding, carrying three of the four men working on top with it.

SUPPLY PUMPS FOR INTERNAL-COMBUSTION ENGINES.

WITH a view to simplify the valve arrangements of internal-combustion engines of the 2-stroke type, the air and gas supply pumps shown in the accompanying illustrations have been designed and patented by Messrs. Mather & Platt, Ltd., Salford Ironworks, Manchester, in conjunction with Mr. A. E. L. Chorlton. Fig. 1 shows sectional views of one form of the pump, and Fig. 2 is a valve diagram of the pump. Fig. 3 is a section of the pump with stationary cylinder and sliding open-ended sleeve. The double walled fixed cylinder or outer casing A is divided by a horizontal partition into gas and air chambers D and E, these in their turn being divided by a vertical partition into inlet and outlet chambers, with gas inlet F and outlet G, and air inlet H and outlet J, and corresponding ports K, L, M, and N. B is the sliding sleeve valve driven through the lug at the lower end, and provided with gas inlet ports O and air inlet ports P at one side and gas and air outlet ports Q and R at the other side. C C are

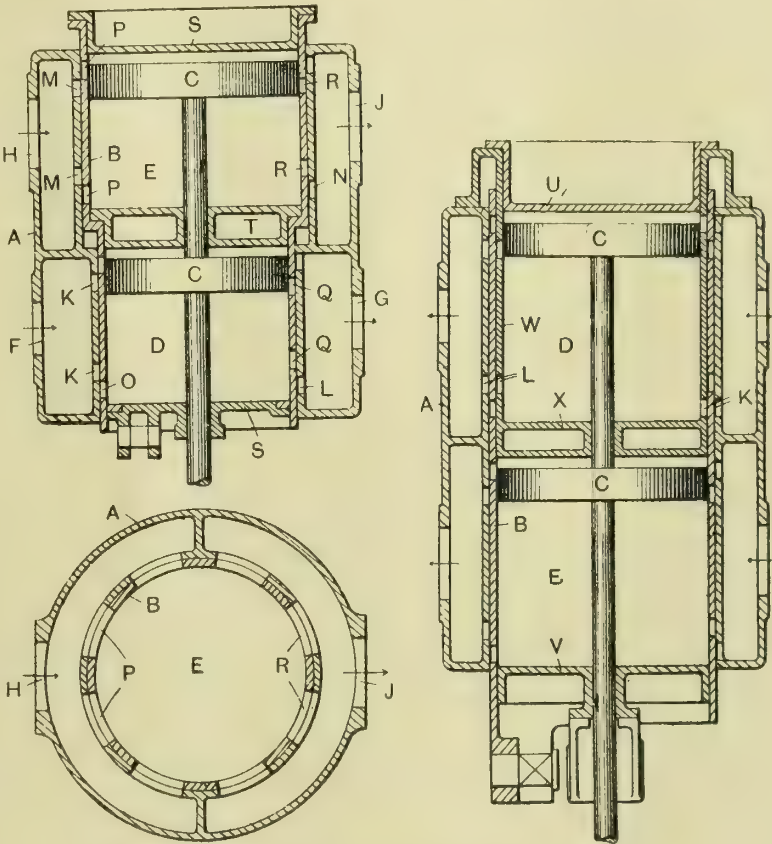


FIG. 1. FIG 3.
SUPPLY PUMPS FOR INTERNAL-COMBUSTION ENGINES.

the pistons, one for air and the other for gas, fixed in tandem on the piston rod.

In Fig. 1 the air chamber E is of greater capacity than the gas chamber D, and the casing and sleeve are stepped to provide for this, as shown. The sleeve forms a sliding cylinder, having end covers S and a central partition T dividing it into separate chambers for the air and gas. The sleeve or cylinder may be driven so that its movement partially opposes that of the pistons, an eccentric or other suitable device on the engine effecting the reciprocation. The outlet or delivery ports of the sleeve are so placed that they may be covered by the pistons near the end of their stroke to cut off the discharge, and form a cushion to reduce the shock upon reversal of the reciprocating parts. As the inlet and outlet ports are opposite to each other a straight course is provided for the air and gas from the suction to the delivery side of the pump. The ports are, as shown in Fig. 1, placed at short intervals completely around the sleeve and casing, so as to give as large a channel as possible for the passage of the fluid and thus reduce the frictional losses, especially at high speed.

The cycle of operations of either the air or the gas pump is shown in the diagram, Fig. 2, which indicates, on a circle

representing the path of the driving crank, the points at which the ports open and close. The suction closes at x, at x^1 the delivery opens, at x^2 the piston closes the outlet or delivery port, at x^3 the port is closed by the sleeve, and at x^4 the suction opens. The pump is double acting and the cycle of operations is repeated in both divisions of the cylinder at each stroke.

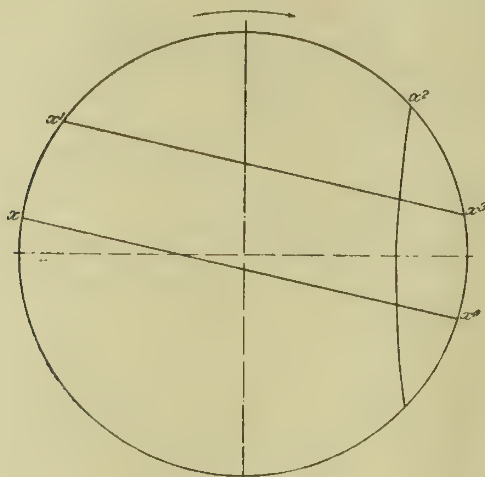


FIG. 2.

In Fig. 3 the sleeve B is open ended, and the fixed cylinder A is provided with end covers U and V and an inner cylindrical extension W carrying the separating partition X dividing the interior into two working spaces. The lower end cover V is mounted on a fixed bracket in any convenient manner. The sleeve B slides at its upper end between the fixed cylinder A and the inner extension W, through which the gas inlet and outlet ports K and L are continued. The cycle of operations is the same as in the pump described above. The air pump is in Fig. 3, below the gas pump, as the lower piston is of greater diameter than the upper one.

THE INSTITUTE OF METALS.

As previously announced, the autumn meeting of the Institute of Metals will be held in London, on Wednesday and Thursday, September 25th and 26th. On the Wednesday morning a selection of papers will be read and discussed. In the afternoon visits will be paid to the works of Messrs. Fraser & Chalmers, Ltd., Erith, or to the National Physical Laboratory. A reception will be held in the evening by the President of the Institute, Prof. W. Gowland, and Mrs. Gowland at the Royal United Service Institution. On the Thursday the morning will be devoted to the reading and discussion of papers. In the afternoon visits will be paid to Woolwich Arsenal, or to the Brooklands Motor Racecourse and Aviation Ground. The following is a list of the papers that are expected to be submitted: (1) Prof. F. Carnevali, Ph.D., on "Autogenous Welding by means of Oxygen and Acetylene of Copper and its Principal Alloys, and of Aluminium." (2) Prof. H. C. H. Carpenter, M.A., Ph.D., on "The Effect of Other Metals on the Structure of the Beta Constituent in Copper-zinc Alloys." (3) Prof. H. C. H. Carpenter, M.A., Ph.D., on "The Structural Resolution of the Pure Copper-zinc Beta Constituent into Alpha plus Gamma." (4) Prof. A. K. Huntington, Assoc.R.S.M., on "The Effect of Temperatures Higher than Atmospheric on Tensile Tests of Copper and its Alloys." (5) F. Johnson, M.Sc., on "The Influence of Impurities in 'Tough-pitch' Copper, With Chief Reference to Antimony." (6) E. F. Law, Assoc.R.S.M., on "The Influence of Oxygen on the Properties of Metals and Alloys." (7) T. Kirke Rose, D.Sc., on "The Annealing of Coinage Alloys." (8) W. Rosenhain, D.Sc., B.A., and D. Ewen, M.Sc., on "Intercrystalline Cohesion in Metals. (With an Appendix on the Formation of Twinned Crystals in Silver.)" (9) Alexander E. Tucker, F.I.C., on "The Joining of Metals." (10) Prof. T. Turner, M.Sc., on "Oxygen in Brass."

THE COMMERCIAL ECONOMY OF TURBINE PUMPS.*

BY F. ZUR NEDDEN AND H. B. MAXWELL.

THE subject of turbine pumps has been dealt with so frequently that the authors must apologise for again bringing it before the Institution. They would, however, claim the right to do so, because, in spite of all that has been written on the subject, those economic questions which are of special interest to the engineer who has to order and to operate high lift turbine pumps have hitherto very seldom, if ever, been touched upon. There is scarcely any machine, except an

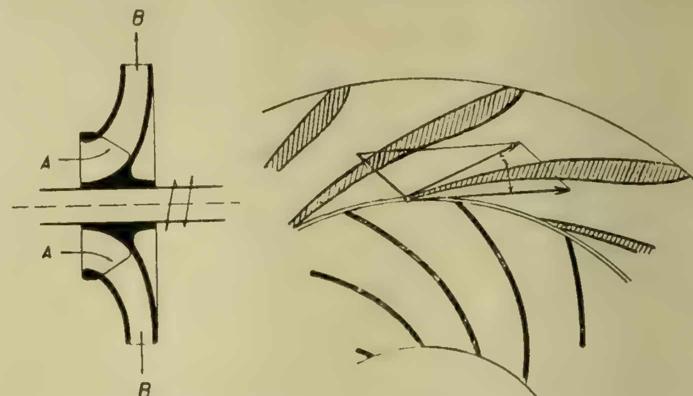


FIG. 1.—ACTION OF THE IMPELLER. FIG. 2.—IMPELLER AND GUIDE CHANNELS.

electrical one, which gives the engineer more riddles to solve than does a turbine pump. Now the reason why all problems connected with rotary machines appear so complex is that one generally does not attack them in the proper manner.

In the ordinary centrifugal pump water enters the centre part of a rotating impeller at A (Fig. 1), and is, by means of blades, seized and given an impetus, thereby producing centrifugal energy, which at B partly exists in the form of pressure and partly in the form of velocity. By catching the water when leaving the impeller and guiding it in channels, the cross-sections of which gradually expand (Fig. 2), the energy which exists in the form of velocity, *i.e.*, the kinetic energy, is fairly effectively transformed into pressure, and only sufficient velocity is left in the water to pass it either out of the pump, or, in the case of a multi-stage pump, into the next impeller. Fig. 3 shows this process in a diagrammatic way. It is essential to note that the full amount of energy transmitted to the water within one so-called stage, consisting of impeller and guide channels, is completely transmitted to the water at point B, and that the guide apparatus does not add to, but only transforms energy.

If several, say three, stages are combined in a way, as shown by Fig. 4 (Worthington multi-stage pump), all that

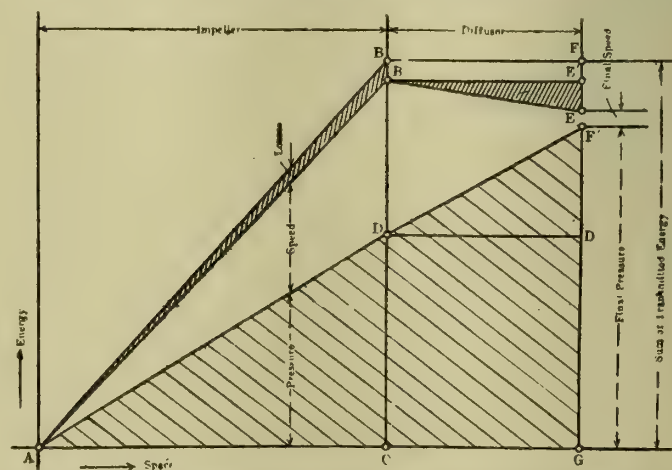


FIG. 3.—ENERGY TRANSMISSION IN A SINGLE-STAGE HIGH-LIFT TURBINE PUMP.

happens is an addition of the effects of the single stages, as shown by Fig. 5, and the authors only show this diagram in order to make it clear that the final efficiency of the process, *i.e.*, the ratio between losses and useful energy, is quite evidently the same as for each single stage. It needs no

* Paper read before the South African Institution of Engineers.

lengthy mathematical deduction to prove this. The geometrical similarity speaks for itself, and shows that:—

$$\frac{A_2 F_2}{F_2 G_2} = \frac{A_1 F}{F G}$$

In other words, only the ratio between loss and useful work obtained in one stage matters, deciding, and being identical

water through the pipeline P. As much water will, therefore, flow out at B as will by its velocity create a friction in the pipeline equal to H – C.

If no counterpressure C is exerted, a definite maximum amount (Q max) will flow out at B, a quantity so great that it flows through the pipe P at a velocity creating a friction equal to the pressure H, therefore just absorbing all the available

TABLE I.—*Test of a Three-stage High-lift Turbine Pump, lifting normally 500 gallons per minute against a head of 335ft., coupled direct to 75 h.p. three-phase alternating-current motor, 1,480 r.p.m. at 50 cycles constant.*

	Test Number.	1	2	3	4	5	6	7	8	9	10	11
Motor. Observed.	Number of revolutions per minute ...	1,480	1,480	1,470	1,465	1,470	1,475	1,480	1,480	1,485	1,490	1,490
	Indicated electric energy, KVA	51·1	62·9	82·7	84·6	84·1	73·8	60·1	57·2	36·8	28·5	24·3
Motor. Calculated.	Motor efficiency according to guarantee η_M %	91·5	92·0	90·5	90·5	90·5	91	92	92	90	88	86·5
	$B H P = \frac{KVA \times \eta_M}{0·746 \times 100}$	62·75	77·8	100·3	102·55	102·0	90·05	74·2	70·4	44·55	33·6	28·2
Pump. Observed.	Pressure head as indicated by manometer, lbs. per sq. inch	148·0	130·0	65·5	4·3	30·0	102·5	134	143	155	154	153·7
	Suction head as indicated by vacuum meter, inches of mercury ..	7·4	7·8	8·4	9·25	9·0	8·4	8·1	7·5	7·2	6·65	6·65
	Level difference between both instruments, H_D in ft	0' 7"	0' 7"	0' 7"	0' 7"	0' 7"	0' 7"	0' 7"	0' 7"	0' 7"	0' 7"	0' 7"
	Delivery, Q in imp. galls. per minute ...	429	579	772	832	809	678·5	546	488·5	234·5	91	0
Pump. Calculated.	Pressure head H_P in ft.	341'	300	153	10	69	236	308	330	357	354' 6"	362' 1"
	Suction head H_S in ft.	8' 4"	8' 10"	9' 6"	10' 6"	10' 2"	9' 6"	9' 2½"	8' 6"	8' 2½"	7' 6½"	7' 6½"
	Total manometric head— $H = H_P + H_S + H_D$ in ft.	349' 11"	309' 5"	163' 1"	29' 1"	71' 9"	246' 1"	317' 9½"	339' 1"	365' 9½"	362' 7½"	370' 1"
	Water horse power— $HPw = \frac{10\,QH}{33,000}$ ...	45·45	54·2	38·2	5·32	19·5	50·5	52·6	50·1	26·0	10·0	0
	Efficiency η% = $100\frac{HPw}{BHP}$	72·5	69·9	38·0	5·2	19·1	56·0	70·9	71·1	58·3	29·8	0
	Notes				Gauge Full Open.							Gauge Closed.

with, the efficiency of the whole pump, no matter how often the process is repeated, *i.e.*, how many stages the water passes through.

So far the theory of turbine pumps is simple. It is not necessary that the intricacies and niceties of the problems of, say, the influence of the form, angles and curvature of blades, the flow of the water both relatively and absolutely, &c., be brought in here, but the question of how such a mechanism behaves under varying conditions can be at once studied. As shown above, each stage or each turbine pump generates a

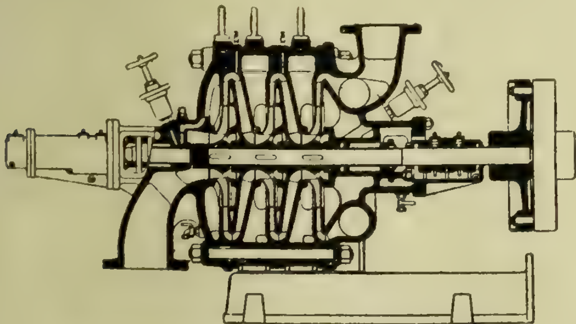


FIG. 4.—WORTHINGTON MULTI-STAGE TURBINE PUMP.

certain amount of energy, which is ready for use at the circumference of any, or the last, impeller. When whirling around with a certain velocity the rotor of the pump therefore represents a constant storage of energy in a similar manner to a tank A (Fig. 6), the water level in which is by some means kept constantly at a certain height H, above the outlet B. If no water is tapped off from the pipeline P, then there is a pressure at B exactly equal to the height H. When water is allowed to flow out at B, by gradually reducing the counterpressure which at first kept the opening at B closed, the quantity of water flowing out always has a definite relation to the counterpressure C, acting against the opening at B. Therefore the pressure difference (H – C) is left for forcing the

pressure. More water, viz. (Q^1 max), can only be driven through the pipeline P and tapped off at B if the height H be increased to, say, H_1. This coherence can be made clear by a diagram as per Fig. 7, and this mode of representation is the key we need in order to understand all the intricacies of the working of turbine pumps and centrifugal machines as a whole. In this diagram the quantities and heights which are co-existent and mutually dependent on each other are, in each

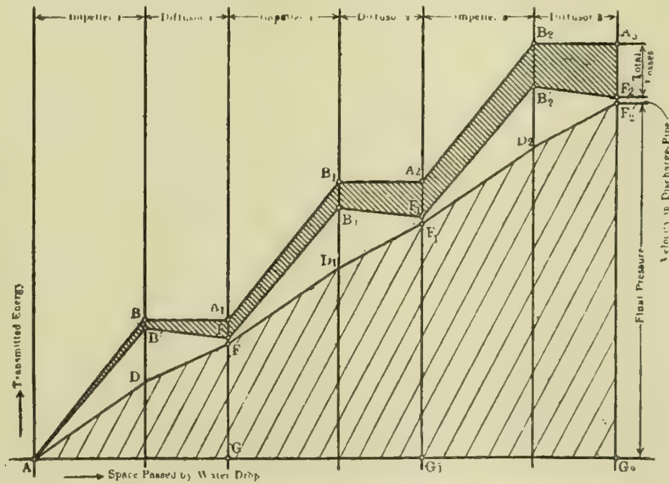


FIG. 5.—ENERGY DIAGRAM OF A THREE-STAGE TURBINE PUMP

case, represented in such a way that over each quantity as abscissa the prevailing pressure is erected as ordinate.

It is important to note that all static heights or pressures, viz., those pressures which are not influenced by the velocity of the flow of the water, must appear as parallels to the quantity axis. The dynamic resistances or pressures, *i.e.*, those dependent on the velocity of the water, also follow a definite rule: they increase or decrease always in proportion to the square of the velocity, and, as the velocity for a given

system of pipes, valves, and openings, bears a direct proportion to the quantity of water flowing through that system per minute, the dynamic pressure is also in proportion to the square of the quantity. Dynamic resistances, therefore, always appear in these diagrams as parabolæ. In Fig. 7 the straight lines A – A and A′ – A′ represent the heights of the tank level above the outlet, and the dynamic resistances of the pipeline P being four times as great for the double quantity OD as they are for the single quantity OB, and nine times as great for OE, the parabolæ AF or A^1F^1 are the result. This diagram now enables us to ascertain at a glance what counterpressure we must exert against the outlet in order to obtain a certain amount of water per minute from the tank, or, put the reverse way, it enables us to tell how much water will flow out if we exert a certain counterpressure, or, put in a third way, it enables us to find how much static pressure and how

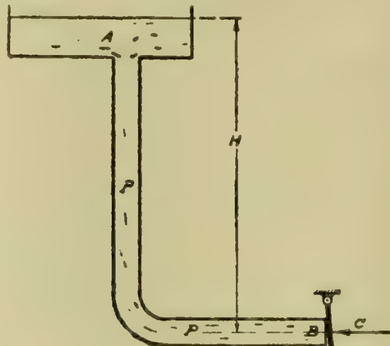


FIG. 6.

much water per minute will be available at the outlet, say, for driving a turbine or feeding a hydraulic lift, if the resistance of the pipeline has a certain value. The curves AF, A^1F^1 are called the characteristic curves of the plant.

A turbine pump behaves exactly in this manner, and its characteristic curve is exactly similar to those shown in Fig. 7. Each impeller generates a certain head or pressure corresponding to the height of that tank, and it only depends on the scale used for the ordinates whether the diagram becomes the diagram of each single impeller or of the whole pump consisting of several impellers coupled in series. (This is important to note when calculating the effect of one or two impellers being taken out of the pump and replaced by dummies.) The

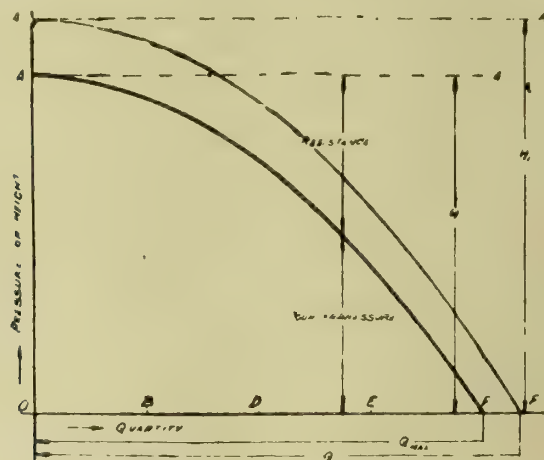


FIG. 7.—DIAGRAM OF OUTFLOW FROM TANK.

resistance of the pipeline P in the former case is, with a turbine pump, replaced by the resistance the channels within the pump oppose to the rapid motion of the water passing through them. The characteristic curve will, therefore, decline rapidly for increasing quantities when the channels in the pumps are narrow or badly designed, and will be "flat" for pumps with wide channels and low velocities of water. These resistances, again, are in direct proportion to the number of stages; this proves the correctness of the statement made above that the difference between the characteristic of one stage and that of many equal stages coupled in series is merely a difference in the scale of the ordinates.

With equal ease it can be shown that, for pumps consisting of several stages working in parallel, the difference of the diagram of the pump, in comparison with that of only one of its stages, is merely a difference in the scale of the abscissæ. We can, however, go even a step further in comparing a turbine pump with a tank, viz., by plotting a curve indicating the power required for each given quantity or head. The turbine pump is a tank automatically filling itself up to a level, viz., that corresponding to its speed (which can, for the present, be regarded as always constant) and the diameters of the impellers. No matter how the energy put in to perform this is afterwards expended, whether the greater amount is used to overcome the internal resistances (*i.e.*, by overloading the pump) or used to produce useful pressure at the outlet, the quantity of water has always to be pumped up to that same height, and the power required for keeping the level of the tank constant is therefore directly proportional to the duty, as it simply represents the product of head and duty multiplied by a constant. In Fig. 8 the straight line OR indicates the power input required for pumping the water up to the level in the tank, or for generating the pressure in the turbine pump. It should be specially emphasized that this power input covers all the losses caused by the flow of the water through both impellers and guide channels. The power is zero for zero delivery, *i.e.*, the pump filling the tank may be idle if no water is taken off, and a certain definite amount of power is required for every duty, which can again be shown by erecting it as an ordinate on the abscissa representing that duty. The result will be a straight line OR forming an angle with the abscissæ, the angle varying with the scale adopted for representing the power.

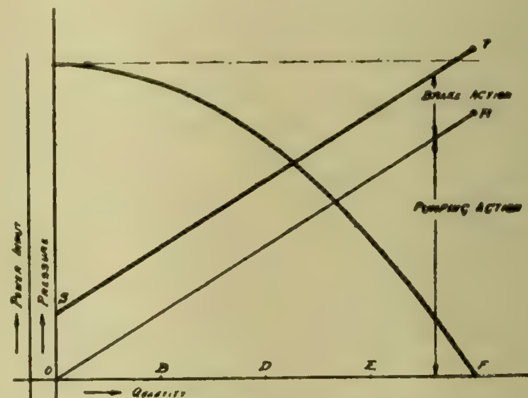


FIG. 8.—COMBINED PRESSURE AND POWER DIAGRAM.

Now, unfortunately, these losses are not the only ones that occur in turbine pumps. There is one type of loss which does not appear in the characteristic curve, but which, as a matter of fact, forms the heaviest percentage of loss in almost every turbine pump. This is the frictional loss caused by the motion of the rotor. Such friction occurs: (1) In the bearings, stuffing-boxes, and bushings of the pumps; (2) where the impellers rotate in the surrounding deadwater. In other words, a turbine pump is not only a pump, but is, at the same time, inevitably a water brake. The amount of energy uselessly expended in this manner is, of course, constant, and independent of the quantity pumped, and, therefore, appears as a straight line parallel to the line OR, viz., ST, in Fig. 8.

The brake energy is in direct proportion to the square of the speed, but also to the fifth power of the diameter of the impellers. The importance of this item of the pump's operation is generally overlooked. This explains why it is not economical to pump small quantities up to high heads with one impeller only, the brake action then exceeds the useful part of the action, *i.e.*, the efficiency becomes low. This further explains the fact that the efficiency of a turbine pump is not exclusively dependent on workmanship and design, as by using many stages, *i.e.*, small impellers, for overcoming the head instead of few large impellers, one can save, by reducing brake losses, what one expends through careless design. Even the scrupulous manufacturer sometimes finds it difficult to draw the line between economy obtained with very correct and scientific design of the blades and channels and good workmanship on the one hand, and that obtained by increasing the number of stages with a cheaper standard of workmanship on the other hand. By a cheaper standard of workmanship is meant not what is known as "shoddy" work, but the simplification and saving effected by standardisation of the blade form for a number of duties instead of designing a new blade

for every duty. The efficiency will in both instances be about the same, but the number of spare parts to be stocked is higher for the pump with more stages.

Returning to the diagram, it is now easy to plot an efficiency curve on the basis of the two curves contained in Fig. 8, as the efficiency is only the ratio between the actual useful energy as shown by curve AF and the energy spent as by curve ST. By erecting the value of this ratio for each particular duty as an ordinate over the abscissa representing this duty, the curve OMF in Fig. 9 is obtained, which, by-the-way, also is a parabola. We see from this that the

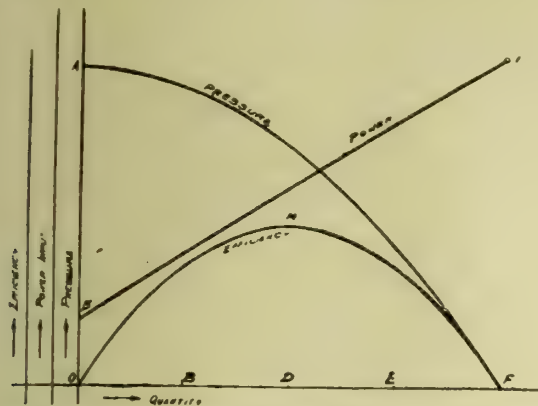
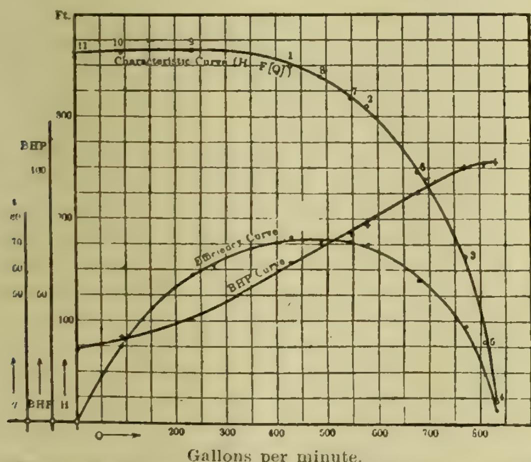


FIG. 9.—COMBINED PRESSURE, POWER AND EFFICIENCY DIAGRAM.

ratio between all losses and the power input is most favourable at one definite duty at M, which we shall call the normal duty.

We have, so far, advanced in a purely speculative manner, and the authors owe you the proof that the theory, in a nutshell, as just developed, really covers the facts to such an extent as to be admissible for practical purposes. Attached is a table containing the results of an ordinary and typical turbine pump test taken on Messrs. Weise and Monski's test bed with a 3-phase 50-cycle motor, *i.e*, running at practically a constant speed. The counterpressure against which the pump is worked on the test bed is generated by throttling the delivery. The text on the left hand of the table contains all necessary information regarding the readings taken off the instruments and the formulæ for working out these readings in the shortest possible manner. The results contained in this table can now be put down in exactly the same manner as were the diagrams above, whereby we obtain Fig. 11. With



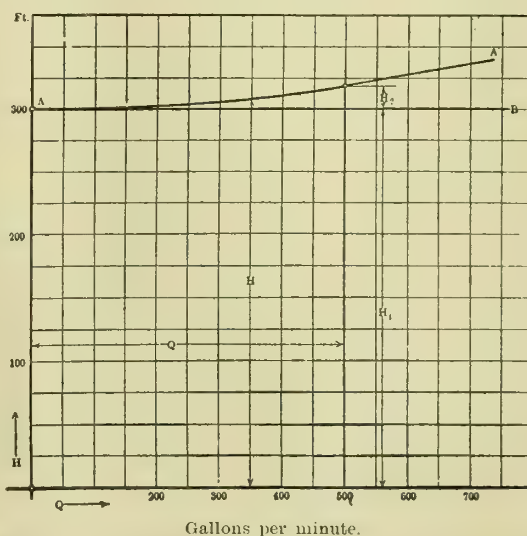
Gallons per minute.
FIG. 11.—DIAGRAM OF THREE-STAGE, HIGH-LIFT TURBINE PUMP, ACCORDING TO TESTS RECORDED IN TABLE I.

the sole exception of the very smallest and very largest duties, which are practically of no importance, eddies being formed in the interior of the pump which somewhat upset regular laws, this diagram coincides with the one developed above.

We might, therefore, now proceed to apply the new method to practical problems. Only a few typical cases can be selected for discussion in the time at our disposal, but the principal object of this paper is to show, by a few examples, the application of the graphical method to practical problems which might then be applied by anybody to the particular problem to be solved. The simplest method by which the fullest light is thrown on the problems to be generally dealt with is to superimpose the pressure diagram of the turbine pump on a counterpressure diagram of the system on which it has to work. These counterpressure diagrams are plotted out on exactly the same principles as the pressure diagrams described above.

Fig. 12 shows the counterpressure diagram of a mine drainage plant in which the pump tested, as per the table given, might be intended to pump. Let the total static height H be 300ft.; the parallel to the axis of abscissæ AB therefore represents the static portion of the resistance for all duties. The resistance H_2 of the pipeline, including valves, &c., will either be known to the user or may easily be calculated by one of the well-known formulæ for one particular duty, say 500 galls. per minute. The friction head will be nil when no water is pumped, it will be one quarter of H_2 when only one-half, *i.e.*, 250 galls., flow through the pipeline, and it will be $\frac{16}{9}$ of H_2 if $\frac{4}{3} = 667$ galls. be pressed through the mains. By putting down $\frac{1}{4}$ H_2 above the line AB at 250 galls., H_2 at 500 and $\frac{16}{9}$ H_2 at 667 galls. per minute, 4 points of the curve indicating the static plus the dynamic resistance of the drainage system are fixed, so that it can easily be traced. The curve A—A¹ therefore indicates exactly what pressure will have to be overcome if any desired quantity is to be pumped to the surface through the existing or planned mains.

Fig. 13 shows both diagrams Fig. 11 and Fig. 12 superimposed and combined, and it might be well to dwell on this



Gallons per minute.
FIG. 12.—COUNTER PRESSURE DIAGRAM OF A MINE DRAINAGE PLANT.

diagram at some length in order to exemplify the value of such superimposing. We read the following from this diagram:—

(1) **Starting of the Pump.**—It is well known that turbine pumps should always be started with their delivery valve closed, thus keeping down the starting torque to the amount of the brake action of the rotor of the pump only. We see that in this case the load thrown on the motor when starting will be 29 b.h.p. (point B on the axis of ordinates) and that the pump will then generate about its highest pressure, *i.e.*, 362ft. water column. When slowly opening the gate valve a part of the pressure difference H_3 is throttled away, and as the throttling resistance gradually decreases, more and more water flows through the pump and mains, until at last, with the gate valve full open, and H_3 therefore having become nil, the pressure of the pump and the natural counterpressure of the drainage system must coincide, *i.e.*, the delivery of the pump will then be about 540 galls. as indicated by the point of intersection P between the pressure and counterpressure curves.

(2) **Motor Load.**—The margin of 17ft. pressure which the manufacturer has allowed over and above the pressure of 318ft., as calculated to be the total head for a flow of 500 galls. per minute through the pipeline, has the effect that the pump throws, with the gate valve full open, about 540 galls. instead of 500 galls., thereby loading the motor to about 75 h.p. The manufacturer, in leaving this margin, only acts in the interests of his clients, for there is, firstly, always the possibility of a slight error either way in calculating dynamic resistances, and, secondly, the pressure generated by the pump will later on decrease owing to wear and tear, so that the user would soon find the duty decreasing below the quantity required and be forced to re-bush the pump. Another reason for providing

for such a margin is that the speed of the motor to which the pump will be coupled on site might be somewhat different even at the exact periodicity of 50 from that guaranteed, or that, for some reason, the periodicity on site might be slightly less than 50. A pump cut down too finely would not then pump the specified quantity. Last of all it is exceedingly difficult to cut down a turbine pump so finely on the test bed that its characteristic curve runs exactly through a previously settled point. There is, of course, a very simple means of reducing too large a margin, viz., by simply reducing the diameter of the points of the impeller blades from which

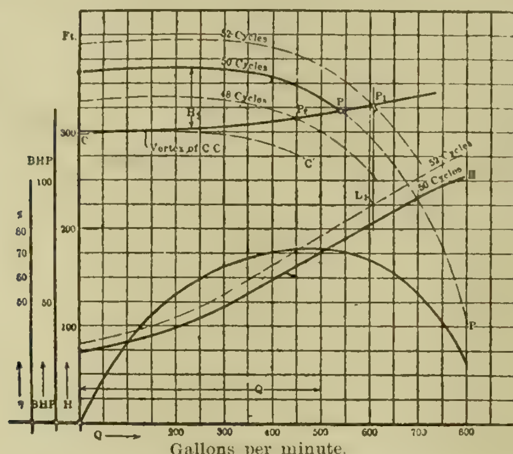


FIG. 13.—COMBINED PRESSURE AND COUNTER-DIAGRAM FOR MINE DRAINAGE TURBINE PUMP.

the generated height depends in the second power. Should, on the other hand, a slight deficiency in pressure be found when testing the pump, the internal losses of the pump might be lessened either by easing off clearances or widening channels whereby the characteristic curve will rise. All this, however, requires patience, money, and time, and especially constitutes an "odd job," which in a factory organised like clockwork requires much more time than under ordinary circumstances. Often, therefore, a larger margin than is absolutely necessary will be left in order not to delay delivery.

This margin, however, upsets a good deal of the calculations on which the figures of the contract might be based. For example, suppose the guaranteed efficiency of this pump be 70 per cent. when pumping 500 galls. per minute against 318ft. This would lead to a normal load of $\frac{5{,}000 \times 318}{33{,}000 \times \cdot 70}$ = roughly, 69 b.h.p. Actually a 72 per cent. efficiency (instead of 70 per cent.) is obtained, but, owing to the margin allowed,

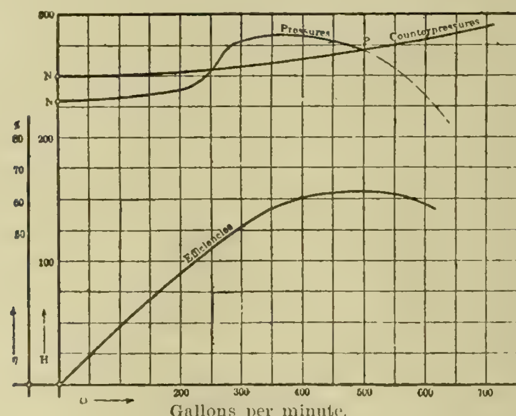


FIG. 14.

the pump requires, with delivery valve full open, 75 b.h.p., *i.e.*, about 8 per cent. more. The margin of 10 per cent. above the guaranteed power consumption usually allowed when fixing the rated output of a suitable motor is, therefore, not due to an uncertainty on the part of the maker regarding the guaranteed pump efficiency, as many engineers seem to assume, but is necessary to cover any increase of power due to the head or speed being slightly different from what was anticipated by both the purchaser and the maker.

(3) **Speed Variations.**—It might in some cases even be advisable to provide for a larger margin, *e.g.*, where the periodicity varies by a few per cent., as is the case in mines where heavy electric hauling motors are taking their current from the same mains as pumps and fans. The authors have seen the periodicity varying from 48 to 52 cycles, in a very well-managed mine, during the periods of acceleration and retardation of the hoists. The effect can easily be read from the diagram Fig. 13 into which the characteristic curves for 48 and 52 cycles are drawn (we shall later on deal with the question how they are plotted in a perfectly simple manner). The delivery will "slide along" the curve P_2PP_1, being 450 galls. at 48 cycles, 610 galls. at 52 cycles, and when drawing the power curve for 52 cycles one finds that the pump then loads the motor up to 90 b.h.p. (point L_1).

(4) **"Snapping off."**—Another very serious consequence of periodicity variations is the occurrence known under the name of "snapping off." Fig. 13 shows that, in spite of the ample excess of pump pressure over counterpressure, it only requires a decrease in periodicity to slightly less than 46 cycles to make the characteristic curve sink down so low that its vertex only just touches the counterpressure curve, when, of course, the check valve will close and the pump run without delivering (point C). It will not "recover," *i.e.*, commence delivering again, before the characteristic curve has again risen so far that an excess of pressure over counterpressure is formed large enough to lift the check valve and accelerate the water column in the rising mains. Re-opening the check valve without its being controlled by the throttling effect of a gradually opened gate valve leads in some cases to fluctuations equally as interesting to the scientific engineer as disastrous to the machinery. Generally, however, no difficulty arises from such "snapping off," provided the blades in the pump are correctly formed.

Fig. 14 shows what happens if this requirement is not fulfilled. The characteristic curve (NP) is obtained by combining an impeller with radial blades with guide channels which open too suddenly. As a consequence heavy eddies are formed under all except nearly normal conditions. They absorb a considerable part of the useful pressure and let it fall even below the static counterpressure (N_1). Such a pump can only be started if previously a part of the water contained in the rising mains is let off, thus easing off the counterpressure above the check valve to less than N. Under normal conditions no serious objection could be raised to such a procedure, as the amount of energy lost in the form of water which had already been raised is trifling. But imagine such a pump working under the conditions described above. Firstly, it will snap off much sooner, as the vertex of the characteristic curve is near to normal working conditions. Secondly, once it has snapped off it will not recover unless the periodicity rises so high as to raise point N above N_1. As it is generally characteristic of electric conditions as described above that the variations in periodicity occur very suddenly and in rapid succession, it will not be possible to run off a little of the contents of the rising mains to re-start delivery, because this would take so much time that probably the pump will snap off again immediately it has been re-started.

(To be continued.)

Miner Electrocuted. — A miner employed at Klondyke Pit, Tolcross, was, on the 4th inst., instantaneously killed while working at the coal face. It is stated that he accidentally caught hold of a live wire connected with a coal-cutting machine.

New President of the British Association.—Sir W. H. White, K.C.B., has been elected president of the British Association for next year's meeting, which is to be held in Birmingham from September 10th to 17th. The following new members of the Council were elected: Dr. Dugald Clerk, F.R.S.; Prof. A. Dendy, F.R.S.; Captain H. G. Lyons, F.R.S.; Sir Oliver Lodge; and Prof. J. B. Farmer.

Fatal Winding Accident at a Mine. — A serious winding accident occurred on the 5th inst. at Shakespeare Colliery, Dover, resulting in the death of two men and slight injuries to six others. A gang of sinkers were at work at the bottom of the pit, 1,000ft. down, when the chain attached to a heavy water tank broke and the tank crashed to the bottom, carrying with it the staging of the pumping installation, and falling on some of the men working below, with the results stated.

GASEOUS EXPLOSIONS.*

In this report the Committee propose to give a short review of the present state of knowledge with regard to the heat-flow from the working substance of a gas-engine into the cylinder walls. It is unnecessary to insist on the importance to practical designers of this side of the theory of internal-combustion engines. It is now fully recognised that a great part of the difficulties experienced in the construction and working of these engines is ultimately due to heat-flow, and the subject has been brought into special prominence in recent years by the introduction of large cylinders in which these difficulties have only partially been overcome.

The rate of flow of heat from the gas to any part of the walls at each instant of time depends upon the then state of the gas as regards temperature, density, and motion, and also on the temperature and condition of the wall surface. It differs widely at different points of the expansion stroke, being far greater just after firing, when the gas is at a high temperature, and highly compressed, than towards the end of expansion. There will, however, be a certain mean rate of heat-flow into any patch of the cylinder walls, and heat must be conducted from that patch on the whole as fast as it goes in. In order that the heat may be conducted away at the required rate there must be a certain temperature gradient in the metal, and there will be a corresponding mean surface temperature. Superposed on the mean surface temperature are variations due to the varying rate of heat-flow at different parts of the cycle. The thermal conductivity and capacity for heat of cast iron are, however, so large that these variations on a clean metal surface must be small—a conclusion which has been verified by Coker, who found a maximum cyclical change of but 7° C. at a depth of 0·015in. in the wall of the combustion chamber of an engine running at 240 revs. per minute. If the metal surface is not clean the variation at the surface of the carbon or other deposit may be much greater.

The important practical question is the mean rate at which heat goes into each part of the surface, and the resulting mean distribution of temperature. The chief problem in designing large gas engines is to control the mean temperature distribution by water-jacketing or otherwise in such a way that the metal does not get overstrained by unequal expansion nor reach a temperature sufficient to ignite the gas. The temperature gradient necessary to sustain the flow of heat from the inside of a combustion chamber to the external water is not likely to exceed 50° C. per inch. At places where the metal is not thick and effective external circulation of water is possible, cooling does not present great difficulty; but at places which are not near to the cooling water, so that the heat has to travel a long way, the temperature must be high to give the necessary gradient. Thus the central portion of the head of an ordinary flat-faced piston if not water-cooled gets very hot, reaching a temperature of perhaps 600° C. in a four-cycle engine of 24in. bore. The piston expands considerably in consequence, the expansion being greater at the centre than at the edge which is accordingly put into tension. In larger cylinders the stresses in the piston set up by unequal heating, and the danger of pre-ignition arising from the hot metal, necessitate the cooling of this part by the circulation of oil or water. Even then the great thickness of metal in certain portions of the combustion chamber, and the difficulty of keeping the water flowing properly in every corner, may cause high local temperatures.

The heat carried away by the cooling water and by radiation is the total given to every part of the walls, and its measurement gives no information on the important question of the manner in which the flow is distributed over the walls. It is certain, however, that the greater part of the heat-flow in a cycle occurs in a comparatively short time just after the moment of ignition, and passes therefore into the surface of the combustion chamber and valves and into the face of the piston. But little goes into the barrel of the cylinder, which is not uncovered until the density and temperature of the gases have fallen. That this must be so is obvious, but the magnitude of the effect is perhaps not generally recognised. Dugald Clerk found in his experiments on the compression and expansion of flame* that the average heat-flow per square foot per second in the first three-tenths of the stroke is three times that of the average over the whole stroke for equal temperature differences, and he calculates that the actual rate of heat-flow in the first three-tenths is six times that of the whole stroke in ordinary gas engines working at full load. This estimate, however, does not include loss due to radiation before maximum temperature. In the actual firing and expansion stroke of a gas engine the difference must be even more when radiation and other losses incurred before maximum temperature are included, and it is probable that in discussing the problem of cooling the metal it is a sufficiently good approximation to neglect the heat-flow into the outer half of the barrel altogether. Prof. Hopkinson informs the Committee that he has worked a gas-engine cylinder of over 30in. diam. in which there was no water circulation round the barrel at all. The whole of the heat passing into the barrel was in this case removed either by radiation or by conduction into the piston, nor was the cooling which was applied to the piston much more than that found necessary on other parts of the walls of the combustion chamber. In small engines with uncooled pistons the water-jacket round the barrel is necessary to keep the piston cool.

In the scientific analysis of gas-engine phenomena the facts stated in the last paragraph are important because they show that the heat-flow is not much different from that which would occur in a closed vessel of invariable volume having the form and size of the combustion chamber, the mixture fired having of course the same composition, density, movements, &c., as in the engine. Some allowance must be made for the fall of temperature and density which occurs in the initial stages of the expansion in the engine, but this will be of the nature of a correction, and will not affect the value of the general conclusions as to the effect of the various factors in heat-flow which may be drawn from closed-vessel experiments.

The Factors in Heat-flow.

1. **The State of the Walls.**—The loss of heat following a gaseous explosion in a confined space depends partly on the state of the gas and partly on the state of the walls of the enclosure. Dealing first with the walls, it is obvious that the higher the surface temperature the less rapid will be the flow of heat, which (generally speaking) depends on the difference of temperature between the gas and the surface. If the metal surface be clean the surface temperature cannot rise by more than an insignificant percentage of the temperature difference; but if it be coated with a non-conducting layer the exposed surface may be heated by the first rush of heat after the ignition to such an extent as materially to check the subsequent flow. For instance, Hopkinson found that a layer of brown paper $\frac{8}{1000}$in. thick pasted inside an explosion vessel of 1 cub. ft. capacity would reduce the rate of heat-flow in the first tenth of a second following maximum pressure by more than 30 per cent. The surface of the paper was not charred, but it must for an instant have reached a temperature of several hundred degrees Centigrade in order to produce such a result. This shows that a badly conducting deposit of carbon in a gas engine may materially reduce heat-flow. Since the high surface temperature occurs just after explosion, it will not necessarily cause pre-ignition, though of course if the mean temperature be high, so that the surface remains red-hot throughout the cycle, it will have that effect.

2. **Radiation from the Gas.**—Of more scientific, though perhaps of less practical, interest is the reduction in heat-loss which is found when the walls are highly polished. This is due to the fact that radiation is an important, if not the principal, agent in the transfer of heat from the gas to the metal. This matter was dealt with in the third report of the

* Fifth report of the committee, consisting of Sir W. H. Preece (chairman), Dr. Dugald Clerk and Prof. Bertram Hopkinson (joint secretaries), Profs. Bone, Burstall, Callendar, Coker, Dalby, and Dixon Dr. Glazebrook, Profs. Petavel, Smithells, and Watson Dr. Harker, Lieut.-Col. Holden, Captain Sankey, Mr. D. L. Chapman, and Mr. H. E. Wimperis appointed for the investigation of gaseous explosions, with special reference to temperature. Presented before Section G of the British Association, September, 1912.

* "Proc. Roy. Soc.," A., Vol. LXXVII. (1906), p. 500.

committee, and it is unnecessary to recapitulate the results there given. It has, however, been carried a good deal further by the researches of W. T. David, who has investigated the relation between the amount of the radiation and the mean temperature of the gas.* He finds that the rate of loss from this cause varies roughly as the fourth power of the absolute temperature. Thus the products of exploding a 15 per cent. mixture of coal-gas and air in a cylindrical vessel 1ft. by 1ft. radiate about 5 gramme calories per square centimetre per second when the absolute temperature is 2,100° C. (maximum pressure), but a tenth of a second later, when the temperature has fallen to 1,700° C., the radiation is only half as great.

In a closed-vessel explosion the rate of heat-flow diminishes with very great rapidity as the gas cools down after ignition. Thus Hopkinson found that the products of igniting a mixture of coal-gas and air in a closed cylindrical vessel 1ft. by 1ft. lost heat at the rate of 10 gramme calories per square centimetre per second at the moment of maximum pressure, when the temperature was 1,760° C. One-fifth of a second later, when the mean temperature was 1,300° C., the rate of heat-loss was reduced to 3½ calories, or only one-third of its value at maximum temperature.† One cause of this is the fact that when the flame first touches the walls the heat is drawn almost wholly from the surface layer of gas in contact with them, and the flow is at first extremely rapid. This

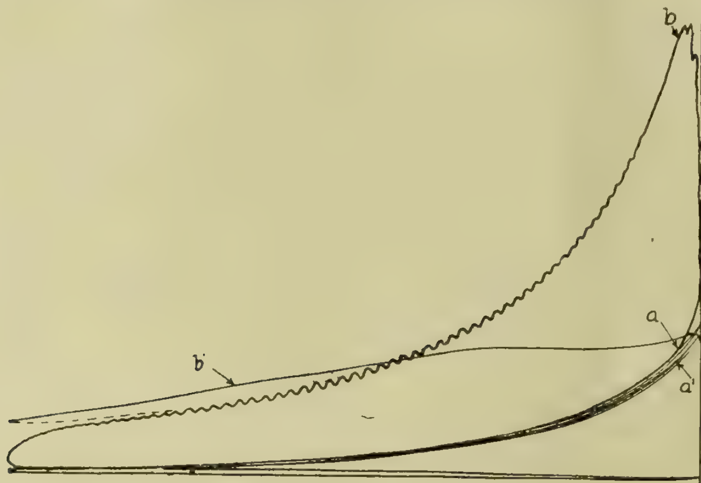


FIG. 1.
Ordinary ignition a to b takes 0·037 second; trapped ignition on third compression; line a^1 to b^1 takes 0·092 second; mixture in both cases 1 volume gas, 9·3 volumes air and other gases.

surface layer soon parts with its heat, and further supplies have to be drawn from the inner portions of the gas, the cool surface layer now acting as heat insulation. But it is probable that the rapid reduction in radiation as the temperature falls is quite as important a factor in this phenomenon. In the gas engine it is, of course, accentuated by the reduction of temperature consequent on expansion. The closed-vessel experiments lend confirmation to the view already expressed, that in the gas engine the rate of heat-flow per unit of area has fallen to a comparative small value when the piston has moved a short distance out on the expansion stroke.

An important practical consequence of radiation is the greatly increased loss of heat which occurs when the mean pressure in an engine is increased by increasing the strength of the mixture. The jacket loss and the metal temperatures are raised in a much greater proportion than the fuel consumption, and the efficiency is diminished. In very large engines this sets a fairly sharp limit to the possible output, which is, as a rule, considerably less than the maximum of which the engine would be capable if it were given all the fuel that it could take. If the load be in excess of this limit the engine overheats rapidly in consequence of the greatly increased heat-flow.

3. The Effect of Cylinder Dimensions on Heat-flow.—At first sight it might appear that heat-flow is a surface phenomenon

* "Phil. Trans. Roy. Soc.," A., Vol. CCXI., p. 375.

† "Proc. Roy. Soc.," A., Vol. LXXIX., p. 138.

—that is, the number of calories per square centimetre per second passing into the walls of an engine or explosion vessel containing a gas at a given temperature and density should be independent of the volume. This view, which is rather widely held, is, however, certainly erroneous, and probably to a considerable amount. The effect of radiation is necessarily to make the heat-loss per unit area from a large volume greater than that from a small volume, because the walls receive radiation from the inner layers as well as from the portions nearer to them. At some depth, of course, the radiation will cease to be sensible, and when that has been reached the radiation from the whole mass will not be increased by further increasing its volume. The experiments of David, to which reference has been made, show that the transparency of the products of an explosion while still at a high temperature is very great, and lead to the conclusion that the heat-loss per unit area from a mass of glowing gas would go on increasing with the volume of the mass until that volume is comparable with the largest sizes of gas engine cylinder now made. David found that the radiation after an explosion in a cylindrical vessel 1ft. by 1ft. was nearly twice as great when the walls of the vessel were highly polished as when they were black. The effect of completely polishing the interior of a vessel is, so far as radiation is concerned, much the same as greatly enlarging the volume of enclosed gas, so that this experiment gives an idea how far the heat loss from the gas in a cylinder 1ft. diam. falls short of that in a very large cylinder. It is quite clear that in a 12in. cylinder the limit of size beyond which heat loss per square foot does not increase is far from having been reached.

One practical aspect of this question is the relation between size and thermal efficiency. This was fully discussed by Callendar in a paper read before the Institution of Automobile Engineers in 1907,* who pointed out that the probability that some part of the radiation loss was proportional to the volume. If heat loss were simply a question of the surface exposed the percentage losses in similar engines should be reduced in proportion to the linear dimensions, and there should be a corresponding increase in efficiency. But in so far as heat-flow increases with the volume, the efficiency of large and small engines will become more nearly the same. Of even greater importance practically is the absolute amount of heat-flow per square foot, since it is this which determines the internal temperatures and so sets a limit to the output of the engine. The results cited show broadly that this quantity must be considerably greater in an engine of say 3ft. bore than in one whose cylinder diameter is only 1ft., and that the difficulty of designing and working the first is not alone due to the greater thickness of metal, but also to the greater heat-flow.

4. The Effect of Density.—The density of the gas in a gas engine explosion is from four to seven times that of the atmosphere. In the Diesel engine it is, of course, very much greater. The effect of this factor is greatly to increase the heat-flow as compared with an ordinary closed-vessel explosion, where the density is that of the atmosphere and the vessel similar in size and shape to the combustion chamber. A rough notion of the magnitude of this effect can be obtained by comparisons of the jacket loss in a gas engine when the total quantity of combustible mixture is altered by throttling or otherwise, the composition remaining the same. It has been found that the total heat carried away from the jackets increases with the quantity of mixture, but not quite in proportion thereto. A similar result is obtained from closed-vessel explosions; it is found that the pressure after firing a mixture of given composition falls relatively less rapidly when the pressure before explosion is higher, but the absolute amount of heat-loss in a given time is greater.† The quantitative relation between heat flow and density seems to be complicated and dependent upon the size and shape of the enclosure. In one experiment on a gas engine of 11½in. bore, the jacket loss varied as $(\text{density})^{0.9}$ when the density at the moment of the explosion was varied

* "Proc. Inst. Aut. Eng.," April, 1907.

† "The Gas, Oil, and Petrol Engine," by Dugald Clerk, Vol. I. (Longmans, 1910), Chap. VII.

from three times atmospheric to about six times.* After an explosion in a cylindrical vessel 1ft. by 1ft., the absolute rate of heat-loss is roughly twice as great when the initial pressure is $1\frac{1}{2}$ atmospheres, as when it is $\frac{1}{2}$ atmosphere, corresponding to the relation† $(\text{density})^{0.6}$"

The relation between heat-loss and density in an explosion vessel is dependent upon two factors—namely, radiation and direct surface-loss by convection and conduction. To a first approximation it may be expected that the heat radiated from a given mass of gas at a given temperature will be independent of the volume which it occupies because the number of radiating molecules is the same. Thus, to obtain from closed-vessel experiments at atmospheric density an estimate of radiation in a gas engine in which the ratio of compression is, say, 5, it would be necessary to experiment with a vessel of the same shape as the combustion chamber, but of five times the volume. From the work of David, however, it would appear that the radiation increases slightly with the density, so that the flame in the gas engine would radiate a little more heat than an equal amount of gas at atmospheric density in the closed vessel.‡ The effect of the other element in heat-loss—namely, convection currents—is probably more affected by the density than is radiation, and may perhaps increase in proportion thereto. The heat-carrying power of the gas depends upon its capacity for heat per unit-volume, and this increases in proportion with the density. Thus it may be expected that the amount of heat transferred to the walls from the interior by a given amount of bodily movement of the gas will increase more or less in proportion to the density. It is therefore to be expected that the combined effect of these two factors, radiation and convection, will be to make heat-loss in a vessel of given form increase according to some fractional power of the density.

The most important practical question connected with the relation between density and heat-loss is the effect of degree of compression on the working and efficiency of gas engines. To put the matter in its simplest form we may suppose that the engine has a cylindrical combustion space and flat-headed piston, so that the enclosure containing the gas at the moment of firing is a cylinder. The length of this cylinder will in most cases be a fraction of the diameter, the ratio of diameter to length being of the same order as the compression ratio of the engine. The problem, then, is to determine how the amount and distribution of heat-loss to the walls is altered when the compression ratio of the engine is changed, say, by lengthening the connecting rod. In the ordinary case of a fairly high compression ratio, the effect of this alteration will be to reduce the length of the cylindrical combustion space without changing its diameter, and to keep the mass of gas confined therein substantially constant so that the density goes up in inverse proportion to the length of the space. At the same time there will be a small rise in the temperature of the fired mixture consequent on the higher temperature before firing. This, however, would not be very much, amounting to about 100° C. for an increase in compression ratio from 4 to 6.

The average heat-loss per square foot to the surface will increase, but not in proportion to the density. On the other hand, the area over which that loss is distributed is reduced, but again in a considerably less proportion than the density. For instance, with an engine of equal stroke bore ratio, having a cylindrical combustion chamber, the result of increasing the compression ratio from 4 to 6 will be to reduce the surface of the combustion chamber by nearly 16 per cent. The density is, of course, increased 50 per cent., and if the heat-loss increases in a greater ratio than the square root of the density, which is almost certainly the case, the effect of this increase of compression would be to increase the total heat-loss, and therefore to diminish the efficiency of the engine relative to the air standard. This in the case supposed would not, of course, lead to any reduction in actual efficiency, because the greater heat loss would be more than counterbalanced by the increase in the efficiency due to increased expansion. But it is clear that if the process were carried sufficiently far the absolute efficiency might also be reduced. Some approach to this state of things was found by Burstall when the compression exceeded about 7.*

The conclusion gained from practical experience, that there is a point beyond which it will not pay to increase the compression in the gas engine, is therefore in full accord with the results of laboratory experiments on the relation between density and heat-flow. Not only is there a point beyond which increasing compression is not followed by an increase in efficiency, but before that point is reached the flow of heat per unit area is increased to an amount at which trouble will begin to arise on account of the difficulty of cooling. It is sometimes supposed that the difficulties which arise from pre-ignition when the compression is increased too far are due in some way to the rise of temperature of the gas consequent on the high adiabatic compression. It is very improbable, however, that this has much to do with the matter. The real cause of pre-ignition is the overheating of some part of the interior surface of the metal or of a deposit thereon, due to excessive heat-flow following an increased density. If the metal could be kept clean and cool, compression could be carried to very much higher values than are now used in practice without any danger of pre-ignition.

The effect of increasing density on heat-loss is, however, a matter on which further experimental evidence is needed. A comparison of the rates of loss after explosions in a series

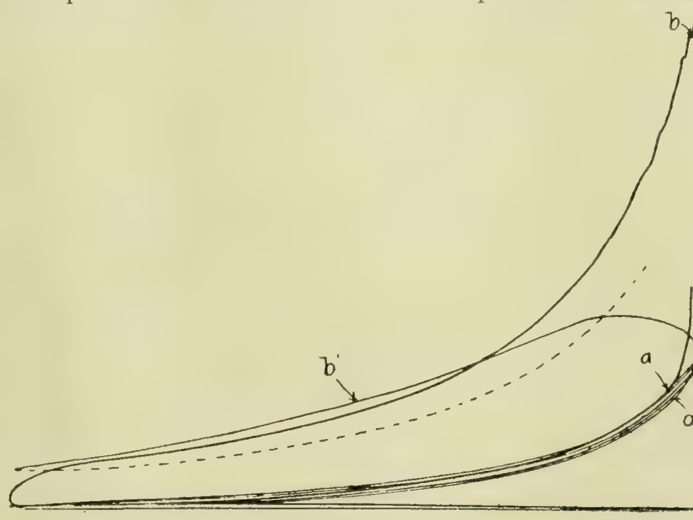


FIG. 2.

Ordinary ignition *a* to *b* takes 0·033 second; trapped ignition on third compression; line a^1 to b^1 takes 0·078 second; mixture in both cases 1 volume gas, 9·3 volumes air and other gases.

of cylinders of the same diameter but of different lengths, the density of the mixture fired being varied in inverse proportion to the length (so as to keep the total quantity constant), would be of great interest. Such a comparison would throw direct light on the heat flow in an actual gas engine if among the cylinders tried were some in which the length was a fraction—say, one-sixth to one-third—of the diameter. In many gas engines the shape of the combustion space is approximately of this character.

5. **Turbulence.**—During the suction stroke of a gas engine, or during the period of injection in an engine charged from a separate compressor, the mixture of gas and air which is subsequently to be exploded enters the engine through the valves or ports at a high velocity, so that the gas within the cylinder is in a state of eddying or turbulent motion. This motion gradually dies away after the valves are closed, but will persist for some time during the compression stroke, so that at the moment of explosion there may still be a good deal of turbulence. In consequence of this motion of the gas the convection of heat will go on more rapidly, and what may be called the "effective conductivity" of the gas will be increased.

Perhaps the most obvious direction in which to look for the effects of turbulence in gas engines is the relation between speed and fuel economy, and this aspect of the matter has been discussed by Callendar, Lanchester, and others. On the one hand, it may be expected that the longer the time taken over the operations of compression and expansion the more heat,

* "Proc. Inst. Civil. Eng.," Vol. CXXVI., p. 234.
† David, *loc. cit.*
‡ David, *loc. cit.*, p. 104.

* "Proc. Inst. Mech. Eng.," 1908, p. 5. See also Prof. Callendar's remarks in discussion on paper by Dr. Watson, "Proc. Inst. Aut. Eng.," Vol. III., p. 457, where the limit of advantageous compression in the petrol motor is estimated as 1 to 5.

other things being the same, will pass into the walls during that period. As against this must be set the consideration that, with a given valve opening, slow speed means less turbulence, first, because the velocity of entry of the gas is less, and second, because the time available for the resulting turbulence to die out under the influence of viscosity is longer. Reduction of speed therefore means less effective conductivity, and it is even conceivable that on this account the heat flow per cycle may be less and the fuel economy greater at the lower speed. The effect of heat flow upon economy is not very marked, and it is therefore not surprising that no decisive verdict has yet been pronounced on the relation between economy and speed. There is no doubt that, given satisfactory ignition, economy is somewhat improved by increasing the speed, but the relation between these two things has not been so precisely determined as to permit a conclusion to be drawn about the part played by turbulence, nor in view of the complication of the question does it seem likely that much information can be derived from this source. A more promising line of enquiry would be a direct measurement of jacket losses at different speeds. The Committee are not aware that any very accurate measurements of jacket loss at different speeds, other conditions being kept rigorously the same, have ever been undertaken. From some rather rough measurements of this character made by various members of the Committee, it appears that the heat loss per cycle does undoubtedly diminish with increase of speed, but not in proportion thereto.

The complete elucidation of the part played by turbulence in the working of a gas engine seems, however, to require more direct methods of investigation than the ordinary tests. During the past year Dugald Clerk has applied his method of indicating the engine with tripped valves, so as to obtain a "zigzag" diagram, to the investigation of this point. During the first expansion line in such a diagram there is present the normal amount of turbulence which obtains in the ordinary working of the engine; during the second and later expansions of the "zigzag" the turbulence has practically died out. We have here obviously a method of considerable delicacy for detecting and measuring the effect of turbulence in causing heat loss on the expansion line. Clerk has found that in the compression and expansion of air or carbon dioxide without firing, the engine being simply motored round, the rate of heat loss at a given temperature is greater in the first compression after drawing in the charge than in the subsequent compressions.

For the purpose of studying by this method the effect of turbulence on heat loss in the ordinary working stroke of a gas engine, Clerk tried the experiment of drawing in a combustible charge into the engine in the ordinary way and then tripping the valves and compressing and expanding this charge for one or two revolutions before firing. By this means the turbulence which, in the ordinary method of working, persists till the moment of firing was given time to die away. It was expected that a comparison of an expansion line obtained in this manner with that following a normal ignition would show the effect of turbulence on heat loss. While the experiment did not give any very clear indication on this point, it was the means of bringing to light a matter of perhaps greater importance. Clerk found that the result of damping down the turbulence was to retard the rate of inflammation of the gas to a very remarkable extent, so that the character of the diagram was completely altered. Two of Clerk's diagrams are reproduced (see Figs. 1 and 2), from an inspection of which the importance of this point in the working of gas engines will be appreciated. If ignition be delayed until the combustible mixture taken into the engine has been compressed and expanded twice and then again compressed, the period of inflammation is about two and a half times that of a normal ignition in which the gases have some turbulent motion. The diagrams shown, Figs. 1 and 2, were taken by an optical indicator from an engine of 9in. diam. cylinder and 17in. stroke when running under full load at 180 revs. per minute. The engine was fitted with two electric igniters; one operating at the charge inlet valve at the back of the combustion chamber, and the other operating at the side of the cylinder close to the piston. In Fig. 1 the back electrical ignition was used, and in Fig. 2 the side igniter was in operation. It has been noticed more than once that the period of inflammation in the gas engine is considerably less than that obtaining in an explosion of a similar mixture in a closed vessel of the size of the combustion chamber, and it must have occurred to many that, were it not for this fact, it would hardly be possible to work internal-combustion engines at reasonably high speeds because the ignition would be too slow. It now appears that this is wholly, or almost wholly, due to the fact that the gas in the engine is in turbulent motion.

Simultaneously with the experiments by Dugald Clerk, described in the last paragraph, Prof. Hopkinson (with the assistance of his pupils, Messrs. Miley and Peache) carried out some measurements of the effect of turbulence on heat loss and inflammation phenomena in a closed vessel explosion. A cylindrical vessel, 1ft. diam. by 1ft. long, was used and was lined with copper strip, the rate of heat loss being measured by a record of the rise of electrical resistance of this strip. A small fan was mounted in the centre of the vessel and comparisons were made of the result of exploding the same mixture, first with the fan at rest, and second when the fan was driven at a speed of several thousand revolutions per minute. These experiments also showed the great increase in speed of inflammation consequent on the motion of the gas. Taking a mixture of 10 per cent. of coal gas and 90 per cent. of air, the time from ignition to maximum pressure with the gas at rest is about 0·13 second; with the fan running at 2,000 revs. per minute this time was reduced to 0·03 second, and at a speed of 4,500 revs. per minute to 0·02 second. The effect on heat flow was also very marked. At maximum pressure, with a 10 per cent. mixture, the rate of flow of heat was approximately doubled when the fan was running at a speed of 4,500 revs. per minute, the mean temperature of the gas in the two cases being the same (about 1,600° C.). It is interesting, however, to note that at the higher temperatures reached with a 15 per cent. mixture—say at 2,000° C.—the heat flow from the gas was not materially altered by the turbulent motion produced by the fan. This is doubtless due to the fact that at such temperatures radiation is an important agent in the transfer of heat, and this would probably be unaffected by the motion of the gas.

For the application of the results obtained with the closed vessel and the fan to the gas engine, it is necessary to get some measure of the amount of turbulence remaining in the latter at the end of the compression stroke. Mr. H. J. Swain, under the direction of Prof. Hopkinson, has made some measurements during the past year bearing upon this point. It is hoped that full details of these experiments, and of those cited above, will be published in the course of the next few months, and the results only need be given here. The method used was to determine the rate of loss of heat from a platinum wire mounted in the combustion chamber of a gas engine, the wire being heated by an electric current. Within moderate limits of temperature the heat loss from such a wire is proportional to the temperature difference between it and the surrounding gas. The ratio between heat loss and temperature difference is a measure of the effective conductivity of the gas, and depends upon its temperature, density, and state of motion. If the first two factors are the same, then the effective conductivity depends only upon the state of motion, and may be taken as a measure of its amount. The wire was mounted in the combustion space of an engine of 7in. bore and 15in. stroke, which was motored round so as to compress and expand charges of air, the gas supply being cut off, and comparative measurements of effective conductivity at the top of compression were made first with the engine valves working in the ordinary way, and second, with the valves closed, so that the same charge of air was continually compressed and expanded, and there was therefore no turbulence resulting from suction. It was found that at 240 revs. per minute the conductivity was more than 60 per cent. greater in the first case than in the second, while at 60 revs. per minute the difference was only about 20 per cent. In these comparative experiments the temperature and density of the gas were the same, and the difference could only be due to the motion. From measurements of the heat loss from a similar wire in the closed vessel, Hopkinson infers that the motion of the gas with a fan speed of 2,500 revs. per minute is probably considerably greater than that obtaining in the gas engine. At this speed the heat flow at a temperature of 1,600° C. or over is increased by an amount of the order of 25 per cent., and, while it is certain that turbulence is responsible for some increase of heat flow in the gas engine, it is improbable that this is such as materially to affect the thermal efficiency, though it is of importance in the problem of cooling. The great influence of this factor on this manner of inflammation which has been disclosed by these experiments of Clerk, and of Hopkinson also, makes the subject worthy of more detailed investigation.

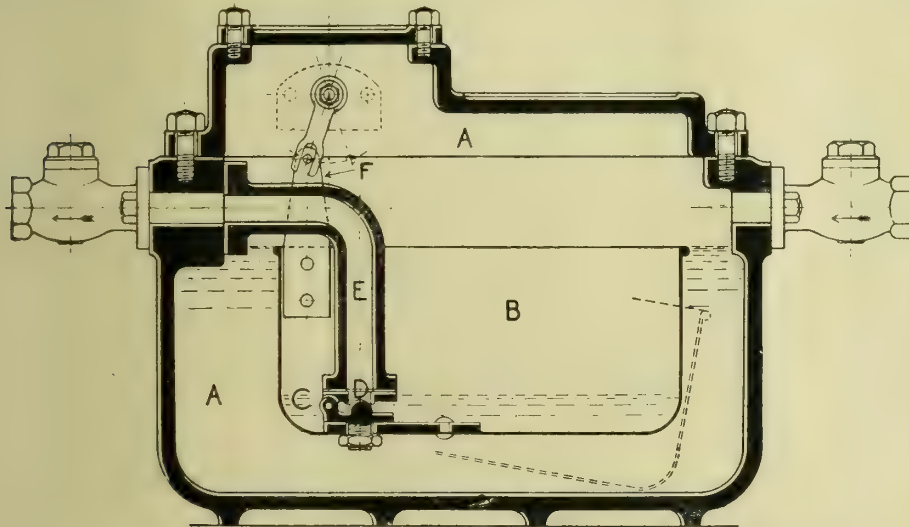
ROYLE'S VACUUM AND SUPER-LIFTING STEAM TRAP.

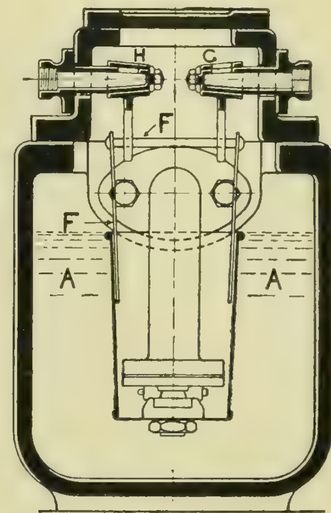
IN draining pipes or vessels under vacuum, or alternately pressure and vacuum, difficulty often arises in releasing the condensed water to atmosphere. This is usually met by some kind of valve mechanism which puts the receiving vessel or trap into communication with the vacuum when filling, and destroys the vacuum in the trap by admitting air during the discharge, but as this air finds its way to the condenser when the trap reverses, it is obviously not good for the vacuum.

The special feature of the Royle's patent vacuum trap, made by Royles, Ltd., Irlam, near Manchester, and shown in the accompanying sectional views, is that no air can enter the trap, the water being discharged to atmosphere by admitting a supply of live steam to destroy the vacuum and discharge to atmosphere. This arrangement has the additional advantage that the power thus obtained can be used to elevate the condensed water into overhead tanks or discharge it at a distance from the trap, regardless of level.

The same mechanism is also useful for discharging condensed water from low-pressure drips into tanks much beyond the height that the trap would discharge naturally. The employment of a supply of live steam admitted at the right moment to do the lifting is a novel feature in traps working under these conditions, and is appropriately named a "super-lifting" action.

The action of the trap is as follows: The float B being empty and at its highest position, and the valve G being open, an equilibrium is thereby established between the trap and the vessel under vacuum requiring to be drained, and the condensed water flows into A through the check valve. Meanwhile the discharge pipe E is closed by the syphonia valve D, and the box is further sealed to atmosphere by the outlet check valve being closed naturally. As soon as sufficient water has overflowed the bucket B to destroy the buoyancy, it falls to the dotted line, so opening the discharge pipe E. At the same time the striker action F operates the cocks G and H, closing G to the vacuum and opening H to the steam supply. The incoming steam rapidly destroys the vacuum and presently exerts sufficient pressure in the vessel or box A to drive the water out viâ E and the outlet check valve. The driving out of the water from the bucket B presently restores its buoyancy and it rises to its former position, and in so doing reverses the valves G and H, and the filling action is again renewed. Obviously with this arrangement the water can be elevated any height required within the limits of the steam pressure available.





ROYLE'S VACUUM AND SUPER-LIFTING STEAM TRAP.

Serious Crane Accident.—Seven men were seriously injured on the 2nd inst. by a crane falling on them on the site of an old synagogue in Great St. Helen's, city of London. A man was driving the crane when, without warning, the centre column snapped and fell with great force upon several men working below. Two of the men were very seriously injured, and one is not expected to recover.

MANUFACTURE OF SEAMLESS STEEL BOILER TUBES.*

BY J. JAY DUNN.

SINCE the time of Watt and Boulton, late in the eighteenth century, the design of steam boilers has been modified, not to say hampered, by the materials available for construction. At that time plates were made of iron by hammering, and were, necessarily, of small size. Tubes, as we understand the term to-day, could not be obtained at all. Trevithick, early in the nineteenth century, was the first to experience, in a marked degree, the limitations placed on this design by available materials, as he was the first to actively advocate the use of higher pressures. It is probable that Watt's antagonism to the use of higher pressures was due to his clear understanding of the numerous forces which were to be controlled. That Trevithick was able to design and build boilers for steam pressures above 100lbs. to the square inch, with the small and poor quality of wrought-iron plates available, is remarkable. Without question, the introduction of the locomotive was delayed at least a dozen years through lack of suitable material, *i.e.*, was delayed until small diameter tubes were available.

The locomotive was not entirely successful until Stephenson, in 1829, equipped the boiler of his Rocket with tubes practically 3in. diam. The boilers for previous locomotives had been designed with a single large flue passing through the boiler, with perhaps one example in which this flue was returned to the firing end of the boiler. The failure, or only partial success, of these early locomotives was due to inadequate supply of steam. The boiler of the locomotive Rocket is typical of all locomotive boilers since designed, there having been no radical changes made down to the present day. The invention of the process of welding sheets into long tubes had an immediate effect on the design of the stationary and marine boilers as well as the locomotive boiler. The introduction of the Bessemer process and improvements in rolling methods made available larger and better sheets for boiler construction. Bessemer sheets were first used for boiler construction about 1862, but it required not less than twenty years to overcome the objections made against the new material. A few years after the period when Bessemer steel plates began to be used in about equal quantities with wrought-iron plates, open-hearth plates became available, and have practically supplanted all other material for boiler construction. Tubes continued to be made of wrought iron until about twenty years ago, when Bessemer steel began to be used for the purpose. The use of steel for tubes has steadily increased, until at this time considerably more steel is used than iron. Open-hearth steel for tubes was introduced by the seamless process. The effort to produce a more satisfactory tube than could be made either by butt or lap welding, led inventors to turn their attention to the production of a seamless tube, the purpose being to

* Paper read before the American Boiler Manufacturers' Association.

eliminate all uncertain ties of the welding operation. Among these early attempts to produce a seamless tube might be mentioned a method of extrusion similar to that used by makers of lead pipe, and the method of casting a short, thick, walled hollow cylinder, the walls of which were afterward reduced by rolling or hammering. One of the first successful processes consisted in forming hollow cylinders and tubes from discs of steel by successive cupping and drawing operations. This method has been applied to the production of all sizes, and is in use to-day for large diameter, heavy wall material.

The real beginning of the present process of manufacturing seamless steel boiler flues was the discovery of Mannesmann, that when a round bar of heated metal is caused to revolve by frictional contact between two surfaces, so arranged as to apply a pressure on the metal along the diameter of the bar, the ends of which are in contact with the two surfaces, a rupturing of the metal occurs along the axis of the bar which was being revolved, causing, or tending to cause, the production of a hole along the axial line where operated upon. Mannesmann's invention, and those of the inventors who followed him, relate principally to the mechanism required to cause the revolution of the heated round bar with the pressure applied under correct conditions, and, at the same time, to give the round bar a forward movement as well as one of rotation, and so control the flow of the metal as to produce a hollow cylinder which would be or could be worked into a commercial tube. The Mannesmann process being an expansion of the metal, which reverses the condition found in ordinary rolling processes, tended to open up any defect in the nature of a seam which existed in the material being worked. The process required ideally perfect steel, which, of course, could not be obtained. A great deal of attention was devoted to the designing of machinery for producing hollow billets by the Mannesmann process, in such a manner that the stresses on the material during operation would be so controlled as not to enlarge or extend defects existing in the material worked.

In 1895 Mr. R. C. Stiefel invented a piercing machine, the object of which was to pierce metallic blanks and billets in a heated state, without subjecting them to a torsional strain which would materially disturb the longitudinal arrangement of the fibres of the metal. The piercing machine invented by Mr. Stiefel is at this time producing the major portion of the seamless tubes used in the United States.

For the manufacture of seamless steel boiler tubes, basic open-hearth steel is used. The steel is made especially for the purpose, every precaution being taken in the melting, casting, and rolling to ensure sound material. The steel used is low in sulphur, phosphorus, and carbon, and usually runs more than 99·25 per cent. metallic iron. The steel is rolled into blooms 5in. to 7in. square, sheared and allowed to cool for inspection. Inspection of the blooms is very rigid. The material which is passed has all surface defects removed by chipping, as is the practice in the production of forging billets. The square blooms are re-heated and rolled into various-sized rounds, the diameter depending on the size of tube which they are intended to make, and the rounds are cut to a length required to give the quantity of metal desired in the finished tube.

The rounds are prepared for the piercing operation by drilling a hole in the centre of one end 1in. diam. and about 1in. in depth. This centring of the round is for the purpose of starting the piercing mandrel centrally, and also to relieve the work on the point of the piercing mandrel at the beginning of the operation. After centring, the rounds are charged to a continuous-heating furnace, where they are heated to a temperature of about 1,225° C.

The essential elements of the piercing machine consist of two shafts, which are parallel and lie in the same horizontal plane. They are adjustable in the direction of their axes, and are held rigidly against longitudinal movement by thrust bearings. These shafts carry discs, bevelled on their outer portion and overlapped in such a manner as to form a pass which first converges and then diverges. The discs rotate at the same speed and in the same direction. They are so related, one to the other, that the sum of the radius of one disc to a given point of contact of the disc with the billet and the radius of the other disc to its given point of contact with the billet diametrically opposite to the assumed point of contact of the first disc is constant. This relation results in each successive cross-section of the billet in contact with the disc rotating at the same speed, thus accomplishing the object of the inventor—not to disturb materially the longitudinal arrangement of the fibres.

The piercing mandrel controls the flow of the metal and determines the wall thickness. The piercing mandrel is supported against longitudinal movement by a mandrel bar, which in turn is supported by a thrust bearing. In operation the piercing mandrel supported on the mandrel bar is placed in the correct position relative to the discs. The heated round billet is brought into contact with the discs, which cause it to rotate and at the same time feed forward on to the piercing mandrel, first reducing the diameter of the billet, then expanding it as the metal flows over the piercing mandrel in the form of a tube. The feeding of the billet on to the piercing mandrel is accomplished by holding the billet by means of guides in a horizontal plane above or below the horizontal plane containing the axes of the disc shafts.

After the billet has passed entirely over the piercing mandrel the mandrel bar is withdrawn, and the hollow billet is removed from between the piercing discs and transferred to the rolling mill, for the purpose of reducing the wall to its final thickness and removing corrugations left on both inside and outside surfaces of the tube by the piercing operation. The rolling mill consists of an ordinary stand of two-high rolls, the rolls containing grooves of the diameter required by the finished tube. Lying within the grooves of the roll is a rolling mandrel, which is supported against longitudinal movement by a bar which is in turn supported by the framework connected to the mill housing. The hollow blank from the piercing mill and in the piercing heat is started between the rolls, which draw the pierced billet over the rolling mandrel, reducing the wall to the required thickness.

From the rolling mill the tube, which is now of approximately the finished diameter and of the finished wall thickness, is transferred to the reeling machine. The work of this machine is to eliminate any variation in the wall thickness left by the rolling mill and to smooth up the interior and exterior surfaces, particularly the interior surface, which may have become somewhat scored by the action of the rolling mandrel. In the reeling machine the movement of the tube is identical with its movement in the piercing operation, *i.e.*, the tube is caused to rotate about its axis and at the same time to advance in a longitudinal direction. In the reeling machine, however, the discs of the piercing mill are replaced by rolls whose axes, while in parallel planes, are inclined to each other. The reeling mandrel is supported by a mandrel bar, as in the piercing operation. The piercing and reeling operations are identical, except that whereas in the piercing machine the piercing mandrel was conical, in the reeling machine the mandrel is cylindrical, the rounded end of the mandrel simply facilitating the entry of the mandrel into the interior of the tube. In reeling, the rolls carried by the shaft are brought into contact with the tube with the reeling mandrel in position. The walls of the tube are under pressure between the surface of rolls and reeling mandrel, the movement of the rolls imparting a motion of rotation and translation to the tube, bringing the reeling mandrel into contact with every point in the interior of the tube, producing a uniformly smooth surface of both interior and exterior.

From the reeling machine the tube is delivered to the conveyer of the sizing mill, which brings the tube accurately to diameter. From the sizing mill the tube passes through a cross-rolling machine for straightening, and is delivered to the cooling table. On the cooling table the tubes are kept from coming in contact with each other, and are revolved slowly to ensure even and gradual cooling.

From the cooling table the tubes are handled by crane to the inspection benches, where they receive inspection for surface. All tubes which pass this inspection are conveyed by crane to the cutting-off machines, where tubes are cut to

length. From the cutting-off machines the tubes are rolled down to the hydraulic testing machine. In this machine all boiler tubes are subjected to an internal hydraulic pressure of 1,000lbs. per square inch, for the purpose of detecting any weakness which may have passed surface inspection. From the testing machine the tubes pass to the inspectors for gauge. After passing inspection for gauge they are stencilled and are then ready for shipment.

When tubes are to be finished cold-drawn, the hot operations are identical with those just described. The diversion in the process starts after the surface inspection as the tubes come from the cooling table. Tubes which are to be cold-drawn, after passing the surface inspection, are taken to the pointing hammers, where the end of the tube is reduced so that it will pass through the drawing die. After pointing the tube is pickled to remove all mill scale; it is then washed to remove all traces of acid, then dipped into a solution of flour and tallow, which coats all surfaces inside and outside, and acts as a lubricant in the drawing operation.

The cold-draw bench consists essentially of a framework supporting a driving mechanism that gives travel to a heavy steel chair. A carriage, with arrangement for gripping the pointed end of the tube and for making connection to the moving bench chain, travels on the framework of the machine. The die, of the correct diameter for forming the outside of tube, is supported in a suitable holder. The mandrel, of the correct diameter for forming the inside diameter of the tube, is carried on the end of a long rod, which is adjustable longitudinally, and is anchored at the rear of the framework, so that the mandrel and dies are maintained in correct relation.

The tube to be drawn is placed by the workman on the bench with its pointed end extending through the die so that it may be gripped by the carriage. The mandrel is then inserted into the inside of the tube and the carriage connected to the moving chain. The tube is pulled through the die and over the mandrel, reducing its diameter and its wall thickness. This work is done cold. The operation hardens the material, so that annealing is necessary if further cold-drawn operations are to be done on the same tube or to fit it for most purposes for which tubes are used. This annealing operation is conducted in large furnaces designed to give accurate temperature control, the temperature being observed by pyrometers, so that uniform results may be obtained.

In its inception the seamless tube owes its origin principally to the desire to eliminate the uncertainties of the weld which existed in all other classes of tubes. This uncertainty exists to-day in welded tubes, but is not, probably, a matter of grave importance, as modern methods and materials, combined with rigid inspection, ensure welds which will resist stresses occurring in boiler tubes, but it is still desirable to eliminate any uncertainty where it can be done without introducing others of greater moment.

The manufacture of seamless steel tubes, as carried on to-day, not only eliminates the weld as a possible sort of weakness, but the operation is so conducted as to leave the material in an ideal physical state. Throughout the hot operations there is a constant breaking down or refining of the grain of the metal, and at no time is this grain size raised by heating operations.

The influence of the structure of the material in tubes on the physical properties is most markedly shown in impact and vibratory tests, the grain size having only slight influence on the tensile properties. Tensile tests of seamless steel boiler tubes give the following average results:—

Hot-finished boiler tubes: Elastic limit, 40,300lbs. per square inch; ultimate strength, 57,400lbs. per square inch; elongation in 8in. 30·00 per cent.; reduction of area, 50·02 per cent.

Cold-drawn boiler tubes: Elastic limit, 29,300lbs. per square inch; ultimate strength, 52,600lbs. per square inch; elongation in 8in., 34·00 per cent.; reduction of area, 53·5 per cent.

The high elastic ratio of the hot-finished boiler tube is characteristic of the material, and is due to the continuous working of the material in the process of manufacture until the temperature has dropped to the critical point. This high elastic ratio is combined with only slightly less ductility than is shown by the cold-drawn tube. The high elastic limit enables the hot-finished seamless tube to stand the large but unknown stress which occurs in boiler tubes due to temperature variation.

The tensile properties of the seamless cold-drawn tube depend almost entirely on the temperature at which it is annealed. It is standard practice to anneal cold-drawn boiler tubes at the lower critical point of the material, in order that all strains due to cold-drawing may be removed with certainty. As a matter of fact, the stresses due to cold-drawing are eliminated at a temperature approximately 100° C. below the lower critical point. This annealing temperature gives physical properties comparable with those of welded steel tubes, and with a much higher elastic limit and greater ductility than can be obtained with iron.

Any consideration of the corrosion-resisting qualities of seamless steel tubes must be comparative, as conditions of service vary so widely. Until there is some argument as to the theory of corrosion, it will be impossible to speak of corrosion in absolute terms. Speaking generally, the steel tube is superseding the iron tube in locomotive boilers, while in marine boilers for the Government the iron tube has been entirely displaced. The largest manufacturers of water-tube boilers for stationary service use seamless steel tubes almost exclusively. This indicates, broadly, that the steel tube is a decided improvement.

Rear Admiral John D. Ford, in a paper read before the American Society of Naval Engineers, gives the following results of an elaborate series of corrosion tests.

Average loss in weight per square inch after 64 weeks, compared with iron, as 100.

1. Hot-drawn seamless steel, open-hearth, 93·7.
2. Lap-welded Bessemer steel, 94·5.
3. Cold-drawn seamless steel, open-hearth, 101·3.
4. Charcoal iron, 100.

Mr. Ira H. Wooldon, member of the American Society of Mechanical Engineers, from an investigation made by him while in charge of the testing laboratory at Columbia University, concludes: "In my judgment, from the evidence collected, there was absolutely no difference in the corrosion of the two classes of pipe (wrought iron and steel). They appear to be equally susceptible to the attack."

Mr. P. DeC. Ball, of St. Louis, in a paper, "Steel Pipe *v.* Wrought-iron Pipe in Refrigerating Work," concludes: "From 33 years of personal observation, construction, erecting, and operating ice-making and refrigerating machines, absorption and compression types, and using iron pipes for the first fourteen years and iron and steel pipes for the next nineteen years, we are convinced that local conditions only govern the corrosion of pipes in refrigerating and ice-making machines, and that, chemically and mechanically, mild steel pipe meets the requirements of the refrigerating engineer in all respects, and better than any other pipe, for the reason that it is superior in point of finish, strength, strength of seam and uniformity of material."

From all data obtainable the fair-minded conclusion must be that there is no marked difference in the corrodibility of iron and steel.

Admiralty and Oil Engines.—Some reports which are current rather exaggerate, says "The Glasgow Herald," the extent to which the Admiralty has definitely committed itself in respect of oil engines. A tank ship, which is to have Diesel engines by Messrs. J. S. White & Co., Cowes, is to be built at Devonport, and another which is to have Diesel engines made by Messrs. Vickers (Limited), is to be built at Barrow—by Messrs. Vickers, of course. The designed capacity of each of these vessels is said to be about 1,000 tons, so that neither is what can be called an ambitious project, although it goes without saying that both will be very interesting vessels. The only other oil-engined ship which the Admiralty has definitely decided to build is the larger tanker. The tenders for it are still under consideration. There are enquiries out, however, for a number of motor boats of the types now carried by war vessels.

MAVOR & COULSON'S SYSTEM OF LUBRICATION.

A SYSTEM of forced lubrication, more particularly adapted for use in conjunction with coal-cutting machines and with high-speed enclosed air engines, has recently been patented by Messrs. Mavor & Coulson, Ltd., 47, Broad Street, Mile End, Glasgow. In this system the oil contained within a well is raised and projected upon the parts to be lubricated by means of air under pressure derived from the source provided for serving the engine, or generated by apparatus driven by the engine, and after use is drained back into the well, if required. Fig. 1 shows sectional views of the system applied to an engine having a single crank, Fig. 2 shows the oil distributor, and Fig. 3 its application to an engine having more than one crank.

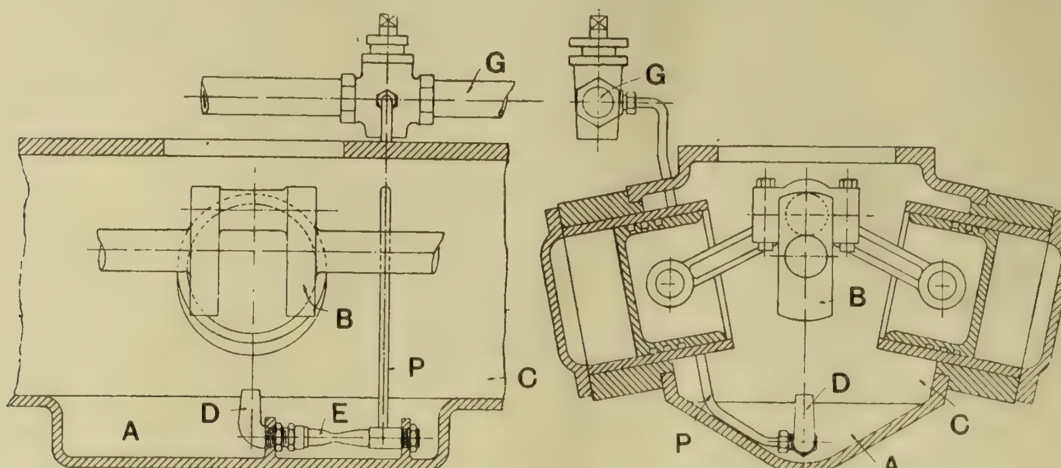


FIG. 1.—MAVOR & COULSON'S SYSTEM OF LUBRICATION.

Referring to Fig. 1, a well A is arranged below the level of the crank B, into which oil introduced into the crank case C is adapted to gravitate. Within the well A and axially directed towards the parts to be lubricated is an oil distributor E, which, as shown in Fig. 2, consists of a sleeve E, furnished at one end with apertures S for the free passage of the oil from the well into the sleeve, and, at its other end with a nozzle D for distributing the oil on to the parts to be lubricated. Within the sleeve E a nozzle F is axially arranged with its mouth pointing in the direction of the distributing nozzle D and connected by means of a pipe P with a supply of air under compression obtained from a supply pipe G which serves the engine. In action, with the sleeve E charged with oil and air under pressure issuing from the nozzle F, the oil is projected from the nozzle D upon the parts to be lubricated. By this arrangement it is not essential that the well A should be disposed immediately beneath the crank pin, although this arrangement may be adopted. In consequence of the force with which the oil can be projected, the oil may be deflected on to parts which are not in the direct line of projection, by providing, for example as shown at Fig. 3, deflectors H for the oil to impinge against and from thence pass to the desired parts. In application to engines having two or more cranks, as shown at Fig. 3, an oil distributor is arranged between adjacent pairs of cranks, and the oil projected from the distributor may be distributed so as to serve the two cranks by being directed through two nozzles D. In other cases, more than two cranks may be arranged to derive their supply of lubricant from one oil distributor.

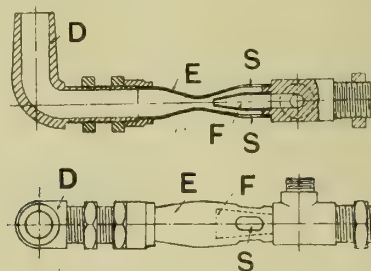


FIG. 2.

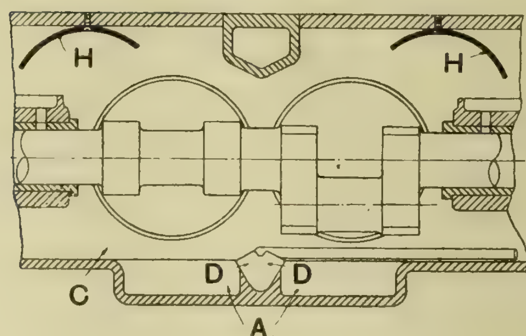


FIG. 3.
MAVOR & COULSON'S SYSTEM OF LUBRICATION.

EXPERIMENTS IN COLOUR BLINDNESS.

SOME interesting experiments in colour blindness are recorded by Mr. George J. Burch, F.R.S., in a memorandum for the Departmental Committee on Sight Tests. Mr. Burch states that his special knowledge of colour blindness began with the discovery that by exposing his eye to direct sunlight in the focus of a lens behind a screen of red glass he could render himself for a time completely colour blind to red, so that scarlet geraniums appeared black, red roses appeared blue, and he made the same mistakes in matching skeins as are made by the red-blind. Further investigation showed that other colours produced analogous but different effects. The sensations during artificial colour blindness, says Mr. Burch, are very impressive, and not easily forgotten. During red-blindness the world looks curiously sombre—all the brilliancy seems to have gone out of it. The general effect is depressing. Yellow objects look green, and the orange parts of them darker instead of brighter; but the yellow is not of a brighter green than the young green leaves, which have the colour of green paint. Blue flowers remain blue, but free of any red tinge, *e.g.*, Canterbury bells look bluer, but more dull. During green-blindness the brilliancy of the landscape is unchanged, but everything looks dry and dusty. Most flowers retain their colour, but the foliage is grey. The effect is suggestive of a pencil drawing with tinted flowers. When the green-blindness subsides it is as if Naples yellow were added to the palette. During blue and violet blindness the landscape appears to lack white. The grass and the trees are of that peculiarly brilliant green that one sees in the paintings of some of the Impressionists. To the eye not rendered colour blind the scenery appears chalky by comparison.

Launch of an Australian Cruiser.—The Australian cruiser "Sydney" was launched from the yard of the London and Glasgow Engineering and Iron Shipbuilding Company, Ltd., Govan, on the 29th ult. She is the sixth ship of the Australian fleet, and is one of four protected cruisers provided for under the 1910-11 programme. These four vessels, which have a speed of 26 knots, are designed as light unarmoured ships, intended for reconnaissance work in association with the more powerful armoured cruisers of a fleet. The dimensions of the "Sydney" are as follows: Length between perpendiculars 430ft., extreme breadth 49ft. 10in., mean draught 15ft. 9in., and a displacement of 5,400 tons. The propelling machinery, of 25,000 h.p., is of the Parsons turbine type, driving four shafts in three separate engine-rooms.

OIL ENGINES FOR MARINE AND LAND PURPOSES.*

BY C. LAKIN-SMITH, M.I.E.E., A.M.I.M.E.

THERE can be no question that we are on the eve of a revolution as to the position the oil engine is destined to occupy in the immediate future and it can now with comparative safety be described as the modern power. If we look back over a period of 25 years, we find that it was then used in quite small sizes mostly for domestic purposes, and its best friends did not consider it a serious competitor with gas or steam. The idea, however, of internal-combustion engines is by no means a modern one, as we can go back a very long way and read of attempts being made with the use of gunpowder as fuel, though these early engineers did not apparently find it necessary to keep records of fuel consumption, &c. The wonderful and rapid changes of the last few years have resulted in the oil engine being practically universally adopted for automobiles, aeroplanes, &c., and not only to its being in keen competition with gas and steam for all purposes except for the largest horse-powers, but in excelling these competitors, at anyrate on the very important point of fuel consumption, particularly whenever standby losses and a low load factor have to be reckoned with.

Engines of the Diesel type are now being built up to 7,200 h.p. in six cylinders of 1,200 h.p. each, and the Diesel Engine Company state that they are prepared to accept orders for 9,000 h.p. engines in six cylinders of 1,500 h.p. each, and other firms are experimenting with even higher powers up to 2,000 h.p. per cylinder. The somewhat popular idea therefore that the oil engine can only compete for the small work is erroneous. There is no class of work to-day where the oil engine is not represented, and I cannot even exclude railway work, as an experimental Diesel locomotive of 1,000 h.p. and also a rail motor of 200 h.p. are already accomplished facts.

For canals the oil engine is destined to play a most important part and may prove itself their salvation. On the Grand Canal Company's system in Ireland there are now 48 barges fitted with Bolinder crude oil engines, and there are a large number in use and on order for this country. The usual horse-power employed for a barge 70ft. by 7ft. is 15 h.p., which enables two other barges to be towed, and, taking into consideration the additional cargo capacity available of 5 to 7 tons, it can safely be said that the oil engine can be used at one-third the cost of a steam engine, and a further point in their favour is that neither constant nor skilled attention is necessary.

This almost sudden popularity of the oil engine for all purposes, apart from the question of the larger powers now available, is due (1) to the demand for lower fuel costs; (2) to the demand for a saving in weight and space; (3) to the demand for a fuel that can be more easily handled and stored; and last, but by no means least, the great improvement recently made in the manufacture of these engines.

The different types of oil engines, as applied to general purposes, will now be considered, their particular applications to marine work being dealt with later on. I would mention here that my remarks refer to the single-acting engines only, as I believe this type of engine has come to stay, for the range of sizes now made, though for still larger sizes, above, say, 2,000 h.p. per cylinder, the double-acting engine will probably have to be adopted in spite of its obvious complications. In comparing steam and oil engines it must always be borne in mind that in the one case the working fluid is entirely manufactured outside the cylinder, whereas in the other case its manufacture is completed inside the cylinder. The classification of the various types can be done in many ways, with numerous subdivisions, but they must at anyrate be classified as 2-cycle and 4-cycle engines, the Diesel, the hot bulb type, some using the heavier and some the lighter oils. I would point out that, the Diesel engine being in a distinct class of its own and dealt with separately later on, many remarks speaking generally of the oil engine do not necessarily apply to this type.

The 4-cycle Engine.—The operation of the 4-cycle engine, better known perhaps as the Otto cycle, which gives a working stroke every two revolutions, is too well known to need a full description, and it will suffice to say that after the working stroke the next three strokes are occupied with the ejection of the exhaust gases, drawing in a fresh charge, and then compressing it. The weaker points in this type of engine are due to its having only one working stroke for every two revolutions, its larger size, and its less regular turning movement, which necessitates the use of heavy flywheels when a regular turning movement is essential.

The 2-cycle Engine.—In the 2-cycle engine, at the end of the working stroke the exhaust and inlet valves or ports are opened almost simultaneously and compressed air rushing into the cylinder is used first as a scavenging charge expelling the exhaust gases and is afterwards compressed on the upstroke of the piston after both valves or ports are closed. The objection to this type lies in the fact that some means of air compressing has to be made which naturally reduces the mechanical efficiency, and thereby increases the fuel consumption from, say, 5 to 8 per cent., and also the fact that increased attention must be given to the dissipation of heat from the cylinder walls owing to there being an explosion at each revolution. If it were not for this loss in mechanical efficiency the 2-cycle engine would be the more economical, as in the case of the 4-cycle engine the gas has more time to become decomposed and to be deposited on the cylinder walls. All 2-cycle engines, however, have a great advantage in addition to the question of size and regular turning movement in being able to be made valveless, which is of great advantage both as regards reliability and the cost of attendance and repairs. The saving in running costs under these last two heads, attendance and repairs, certainly counterbalances and often more than counterbalances the loss in mechanical efficiency, and I venture to think that some engineers, and particularly consulting engineers, often think too much of the last ·001 in the fuel costs and not enough of the total running costs, which of course include the repairs and attendance and other practical points. Before going on to describe the different engines there are certain points that always require consideration, such as the gas, ignition, vaporisation, governing, &c.

Fuel Supply.—In the cylinder of an oil engine the time available for combustion is very small, and consequently it is essential that the gas be such, or fed in such a way, as to ensure almost instantaneous combustion. If the oil is insufficient in quantity the combustion is very slow and there is always then a chance of pre-ignition, caused through a lingering flame still burning when the end of the working stroke is reached. If, on the other hand, the mixture is too highly charged with oil vapour, and there is present insufficient oxygen, the combustion is probably incomplete and a deposit is left in the cylinder and other passages.

Ignition. — Beau-de Rochas, the inventor of the Otto cycle, intended that compression should continue to the point of spontaneous combustion, so as to avoid the complications of ignition devices, but on this point he was wrong, as the temperature of the charge drawn in on the suction stroke would vary to some extent with the temperature of the cylinder walls, depending upon the load the engine was doing, and thus making pre-ignition always likely. Where this form of ignition by spontaneous combustion is used the fuel must not enter the cylinder until the time for firing the charge has arrived, and for other forms of ignition the electric spark, or the hot bulb or tube are usually adopted.

Carburation. — The ordinary method of carburation of the lighter oils such as petrol consists in drawing the air required for combustion at considerable speed through a passage contracted at a point and surrounding a nozzle at which the spirit stands at constant level. In all of the many types of carburetters this is the usual principle adopted, but for the heavy oils external heat is required, and for this purpose the exhaust gases are often used and the apparatus is usually called a vaporiser. In the hot bulb type of engine, however, the matter is more simple, the oil being pumped direct into the ball, which is kept hot by the working of the engine and there vaporised.

Governing. — The governing of an oil engine is a point of particular importance and is often put forward as an objection to their adoption by steam engine makers. There are two principal methods, the one known as the "hit and miss," whereby a working stroke of the engine is entirely cut out, and the other by means of which the supply of fuel is regulated to suit the load and no working strokes are missed. Other methods consist in prematurely opening the exhaust valve or

* Paper presented at the Olympia Oil Industries Exhibition, Sept. 11th, 1912.

keeping it closed, but these are hardly in general use. On light loads the hit and miss principle has the advantage in fuel consumption, the mixture being kept constant at all loads, whereas with the graduated charge the mixture may vary and also the amount of compression. Water injection is now generally used and is found not only to increase the efficiency of the engine, but to allow the compression to be carried to a higher point without increasing the risk of pre-ignition.

Price of Oils.—I do not propose to discuss the question of oils here except as regards the price. We have recently been much inconvenienced by a general rise in price, though this I firmly believe is due to rises in freight rather than in the oil, and cannot last. In January, 1911, a usual freight from the United States to this country was 12s. 6d., but to-day this price ranges from 40s. to 50s. There are now 96 tank steamers building, 54 of them in this country, and it is calculated that as soon as they are at work they will be capable of increasing the tonnage transported by three millions per annum. It is evident from this that at anyrate the owners of these boats realise the increased demand that will be made and that they see no dangers ahead as to the supply of the necessary oil.

Comparative Costs of Steam, Gas, and Oil Engines.—As far as comparative figures are concerned for fuel costs and efficiencies for steam, gas, and oil engines the only means of obtaining accurate and average figures is to use those published in the returns of electricity supply undertakings. Mr. Charles Day, in a paper recently read at Portsmouth, gave the following figures of fuel costs, having worked out the average figure from all central stations up to 1,000 h.p.:—

	Pence.	Load factor.
Steam	·45	14·7
Gas	·43	15·3
Oil	·23	14·3

The figure given here for oil is remarkable by comparison, and emphasizes the large saving to be effected in standby losses on a low load factor, the standby losses very probably amounting to 20 or 25 per cent. The figures he quotes for repairs are also very favourable to oil engines, but as probably the various oil plants were fairly new and the rest of the plants fairly old I have omitted the figures.

Mr. Peiffer, in his paper of May 31st, 1909, gives the following comparative figures for the thermal efficiency at a 52 per cent. load factor, which again shows the superiority of the oil engine:—

Steam	8·7 per cent.
Gas	14·5 per cent.
Oil	27·8 per cent.

All these figures, however, naturally favour the oil engine on account of standby losses alone, but I think the following figures will to-day give a fair comparison for the thermal and mechanical efficiencies, and are ones that we may expect to meet in daily practice, and are not makers' figures or the results of special tests:—

	Efficiency, Thermal.	Mechanical Efficiency.
Steam	10·12%	92% (forced lubrication).
Gas	18·20%	80% " "
Oil	28·30%	74% (4-cycle Diesel).

The Diesel Engine.—A lengthy description of this well-known engine is not necessary. Its leading features are: (1) Carrying the compression up until an ignition temperature has been reached, thus avoiding all ignition devices; (2) Injecting the fuel after the compression is completed, thus avoiding all possibility of pre-ignition; (3) the fuel is injected gradually for $\frac{1}{10}$ stroke, and no explosion takes place; (4) governing is carried out by altering the period of injection as well as the quantity of fuel.

The advance in efficiency made by this engine can be attributed to its high compression up to about 500lbs., and the method adopted of spraying in the oil with a further injection of air at about 800lbs. In the 4-cycle land engine the fuel valve is usually placed in the centre of the cylinder cover, with the inlet and exhaust valves on either side of the ordinary mushroom type, but with removable seats, and in addition a starting valve. In the 2-cycle engine the exhaust valve is dispensed with, though the scavenge air valve is an addition, the other valves being arranged on the cover as on the 4-cycle engine. A separate fuel pump for each cylinder is generally supplied, which has the advantage of making each cylinder independent of the others, and the right supply of oil more certain.

The compressed air for starting is obtained either from a separately driven compressor or by either driving the compressor from the crosshead or by connecting it to the end of the crank shaft, and the scavenge air pump is driven generally by one of the two latter methods. All these details of general arrangement vary with the different makes, each maker striking out a line of his own as the best, but it is impossible here to go into the comparative merits of the well-known makes, such as the Westinghouse, Carels Frères, Sulzer Bros., Mirrilees, Bickerton, & Day, and others. The engines for the largest powers are built with as many as eight cylinders, which is probably the greatest number practicable, and if in this direction the limit has been reached, and also in the sizes of the cylinders, due to the very high pressures and temperatures, we must then fall back on the double-acting engine for the still larger sizes.

The fuel consumption of these engines is not only remarkable for its lowness, but for comparatively small difference between the various sizes. The following are the present guaranteed figures of the Diesel Engine Company for their 4-cycle engine, to which 3 to 4 per cent. must be added for the 2-cycle engines to balance the loss in mechanical efficiency:

25 h.p.	·49lb. per horse-power.
33 ,,	·48lb. ,, ,,
40 ,,	·46lb. ,, ,,
50 ,,	·44lb. ,, ,,
80 ,,	·42lb. ,, ,,
135 ,,	·42lb. ,, ,,
156 ,,	·41lb. ,, ,,

From 150 h.p. upwards, as far as present sizes go, the figure of ·41 appears to remain constant, and thus there is only a difference of ·08 from the smallest to largest. For marine engines the 2-cycle type is almost universally adopted, principally, no doubt, on the grounds of weight and space, though the absence of the exhaust valve is yet another advantage of considerable importance, as exhaust valves have a nasty habit of requiring attention at awkward moments. The present type of engine for marine work is built very much on the lines of a marine steam engine, the earlier higher speed enclosed type having been abandoned. Reversing can be carried out by means of compressed air as rapidly as with the steam engine, and the engines will run quite satisfactorily down to about one-third of their speed. We have here, at the Exhibition, two interesting samples of 4-cycle oil engines, the Westinghouse and Blackstone engine, and another interesting exhibit in Tangyes gas and oil well-boring engine.

Westinghouse Engine.—The Westinghouse engine is of the hot bulb vertical type. One special feature of this engine is that the piston when nearing the end of its upstroke covers an annular chamber or pocket, which on the compression stroke gets filled with compressed air. At the end of this stroke the fuel is injected and fired, and the piston on its downward stroke uncovers the annular chamber, releasing its charge of compressed air, and which, mingling with the burning fuel, makes the combustion complete and ensures greater economy and efficiency. Another feature is an auxiliary air valve placed above the combustion chamber, which ensures its being swept out, a portion of the air being drawn in through this valve on each suction stroke. The governing is done by regulating the stroke of the pump, and no working strokes are missed.

Blackstone Engine.—The Blackstone is a horizontal engine practically of the hot bulb type, but possesses a special dual spraying device, which has the advantage of keeping the ignition at a constant temperature at all loads. This device consists in spraying a main jet of fuel into the combustion chamber, and an auxiliary and constant jet into the ignition chamber. A port is so arranged between the ignition and combustion chambers that the flame in the former impinges on the spray in the latter and ignites it. The fuel first reaches the ignitor-spray, the pump being controlled by the governor, and any oil in excess of the constant amount required overflows into the main spray. These engines work on a low

compression of 150lbs., but the fuel is injected with a charge of air at 450lbs.

Tangye Engine.— The Tangye exhibit is of particular interest, both because it is specially designed as a well-boring engine and because it is a combined oil and suction gas engine, being able to be used for either purpose. This special adaptability of the engine to gas or oil may in some cases, where boring has just been started, be of great value, as no oil might for the time being be procurable. The engine proper is really one of their standard 4-cycle horizontal gas engines, with the various attachments made so that it can also be used as an oil engine, and special attention has been given to the fact that it is likely to work in extremely cold places.

On starting the engine benzoline is used, and on the top of the cylinder is a float tank which, on starting, can, when necessary, be filled with boiling water, but when the engine has started the cylinder jacket water is circulated round it. In about 20 minutes the vaporiser, which is heated by the exhaust, is sufficiently warm, and the crude oil can then be used. The vaporiser consists of a jacket round the exhaust pipe, the crude oil being admitted at the top and flowing all round the exhaust pipe. As the oil flows down the exhaust pipe the lighter oils are given off, and coming in contact with the hot air, which is also exhaust heated and drawn up through the bottom of the vaporiser, are vaporised. The heavier or residual oils are drained off from the bottom of the vaporiser. Magneto ignition is used, and the magneto specially protected from any danger of oil flames. There is a special arrangement to ensure the vaporiser being kept hot enough on light loads by means of lighter charges, and there is also a special attachment for controlling the speed of the engine at a distance by means of a cord attached to a lever on the governor gear.

There are quite a host of different 4-cycle makes of engines too numerous to mention, the Allen Campbell, Crossleys, Tangyes, Dudbridge, Gardner, Hornsby, Westinghouse, Petters, Rustons, Kromhout, and many others. In many main features all these engines are more or less alike, but in the smaller but not less important details, such as valves, vaporisers, and ignition devices, each maker has ideas of his own. The construction generally of the smaller sizes of the horizontal type is akin to the 4-cycle gas engine, and also the methods of operating the valves, the principal differences being, of course, in the vaporisers and ignition devices. Now the 2-cycle engine is quite different. It is usually of the vertical type, and can be made valveless, and has the other advantages previously mentioned as to weight and space, and no need for highly skilled attention.

The Bolinders Engine.—I will give a brief description of the operation of Bolinders crude oil valveless 2-cycle engine, as there are several others, more or less of this type, made by Messrs. Coates, Plenty, & Co., Petters, Ltd., &c. On the upstroke of the piston the charge is compressed, while air is drawn into the crank case through two automatic flap valves. As the piston comes to the top of its stroke fuel is injected into the hot bulb and immediately converted into vapour, and, mixing with the compressed air in the cylinder, is fired. While the piston is then moving down on its working stroke the air in the crank chamber is compressed to about 15lbs. to 20lbs. The piston, now nearing the end of its working stroke, uncovers the exhaust port, and almost immediately after the air inlet port from the crank chamber is uncovered, admitting the compressed air from the crank chamber. The head of the piston is so shaped that the air first rushes to the head of the cylinder, completely scavenging it, and then, as the piston moves upward again, the two ports are closed, and the remaining charge in the cylinder is compressed. An ordinary blowlamp is used for the preliminary heating of the hot bulb, which takes 10 to 15 minutes, and the governing is done by varying the supply of oil to each cylinder. These engines are made in sizes from 3 h.p. to about 320 h.p. the horse-power per cylinder being 80. The fuel consumption ranges from ·54lb. per horse-power per hour in the smaller sizes to ·48lb. in the larger, which, as you will see, is quite a small increase over the Diesel engine.

Oil Engines for Marine Purposes.—The position of the oil engine for marine purposes is now such that every shipowner must be more or less considering the question of its adoption, the results of previous achievements and the number of ships and boats already fitted out having demonstrated its value sufficiently to remove much of the prejudice that may have previously existed, and we have now reached a stage in the history of the marine oil engine when progress will be very much more rapid. It is perhaps remarkable to have reached this stage just at the present time, as it is just a century ago last month that the well-known steamship "Comet" commenced her thrice weekly sailings between Glasgow and Greenock, and during this time, except for the last few years, steam has held its own against all comers and has, to say the least of it, had a fair innings. The "Comet" was the first steamship, at anyrate in this country, to be in regular service, and though many previous attempts had been made it is not at all surprising that they were doomed to failure when one reads descriptions such as the following: "About the year 1795 Lord Stanhope constructed a vessel which was tried in Greenland Dock. The paddles were made in imitation of the feet of a duck and were placed under the quarters of the vessel, but the mechanism did not answer his lordship's expectation."

Now the reasons that are bringing about present changes in marine work are due to the way manufacturers have adapted their engines to suit the particular purpose and the enormous increase in their horse-power, and also to the necessity now realised by shipowners, in times of keen competition, of economising in weight, space, labour, and fuel costs. Apart, however, from the question of economies, there are two points essential for a successful marine engine, the one being reliability, with which one can combine simplicity, as they usually run hand in hand, and the other the question of starting and stopping and, perhaps of even more importance, the reversing. These are the points which in the past made progress slow and which the marine engineer never lost an opportunity of trotting out and using against us on every conceivable occasion.

Reversing. — There are now in use three distinct methods of reversing: (1) The use of clutches and gears in small boats. (2) Reversing the engine by compressed air. (3) Direct reversing of the engine by prematurely igniting the charge on the upstroke of the piston for sizes up to 320 h.p.

The first two of these methods speak for themselves and the time taken in reversing will satisfy all requirements, but the third system of direct reversing has been adopted, I believe, by J. & C. G. Bolinders alone. At the time of reversing, the engine is always declutched and the speed reduced to about 10 per cent. There is no sign of shock or strain, nor has the cylinder or other parts of the engine any extra weight, and the momentum to be overcome on the reversal taking place is only that of a small flywheel, which is small in comparison with a propeller immersed in water. Before I had seen an instance of one of these engines reversing I admit I felt doubtful about it, but in this case seeing is believing, and those of you who have seen, I am sure, will agree with me. The time taken in reversing is less than with any other engine, and although 65 of these marine engines are in use in this country, not to mention a further 107 on order, no accident through reversing has so far been recorded.

All types of engines have at one time or other been tried for marine work, with varying results, but if we keep before us the two vital considerations of reliability and weight then we may at anyrate agree that the 2-cycle engine is the one to be adopted, and at present I should favour the Diesel type for the larger work and valveless hot bulb type for the smaller. Now it is generally admitted that the Diesel engine requires highly skilled attention, and on a large boat carrying a staff of engineers there is no reason why she should not get it, but on the smaller boats matters are very different, and the simplicity of an engine is here of considerable advantage and outweighs the additional 5 to 10 per cent. gained in the fuel consumption of the Diesel even apart from probably smaller costs in repairs.

At present engines have been built, and are now being built, up to 7,200 h.p. in six cylinders, and makers are willing to accept orders up to 9,000 h.p. This means that it is only the really abnormal ships that for the moment are beyond our reach, and although the usual practice is to use two main engines, there is no real reason why a third or even a fourth should not be installed, which would result in our being able to put 36,000 h.p. into a ship, driving the screws direct. In the case of three engines the third would stand of course

between the other two, just as if it was a single-engined ship, and in addition to increasing the reliability might on occasion be used alone with great advantage, particularly when in dock.

For the past few years one has heard from time to time suggestions of electrical drives as a means of obviating any difficulties there might be in manœuvring with oil engines, but more particularly for dealing with the larger horse-powers. The idea consisted in coupling a dynamo to the engine shaft and then transmitting to motors on the propeller shaft, and where the horse-power required was too large for one engine it was intended to employ a large number of generating sets and run them more on central lines. One obvious objection is the weight of the electrical machinery, though the weight might be less than boilers, and although when this idea was first mooted, the possible horse-powers then being much smaller, some useful work might have been done in this direction, it is now too late, and I cannot help thinking that this method, with its many disadvantages, would never have done more than cover the transition stage from smaller to larger engines. It seems therefore remarkable to be reading at the present time of the U.S. collier "Jupiter" being electrically equipped, as this is a first instance of a ship of any size being so equipped.

Owing to the fact that it is only quite recently that ocean-going ships have been fitted with oil engines, it is most difficult or practically impossible to get accurate figures as to the savings in weight and space that have been effected, but to put it at a safe figure, I should say that the saving in weight should amount to 50 per cent., and in space to 45 per cent., the space alone required for the storage of fuel for equal powei being one-third that of coal. What we want for this purpose is an instance of a steam engine being replaced by an oil engine of equal power, but unfortunately no such instance exists, though the ship "Uto" is a good illustration of the economies to be effected. This ship originally had a steam engine of 70 h.p., which was replaced by a Sulzer-Diesel engine of 150 h.p., and, in spite of this large increase in horse-power, the weight of the complete installation was reduced from 14½ tons to 9½ tons, the necessary length of engine-room from 23ft. to 18½ft., and the cost run per kilometre from 9·5d. to 6·34d., the price of oil being 51s.

As an instance of comparative fuel consumption I would quote a test made in two heavily-powered fishing boats during two months of this year, which resulted in a fuel cost of £79. 11s. 2d. for the steam boat and £35. 13s. 8d. for the oil boat, in which was a Bolinder engine. The latest example of a Diesel-engined ship is the "Eavestone," of 4,350 tons displacement, which has just accomplished its maiden voyage and will shortly be in the London docks. The engines are of the Carel-Diesel type and of 800 b.h.p. at 115 revs. per minute, there being four cylinders 20in. diam. with a 36in. stroke. The fuel consumption on the maiden voyage with the two engines working at 650 b.h.p. was ·425lb. per brake horse-power hour per hour. When dealing with the smaller sizes of ships where all types of engines are available, the weights per horse-power are of course in themselves an important feature in deciding the type of engine, and for a 250 h.p. engine the weights for the different types might be as follows:—

Diesel Type.	Hot-bulb Type.	Steam.
21 tons	13 ton.	33

The following is a comparison between a 100 b.h.p. Bolinder-engined ship and a 105 b.h.p. steam engine:—

Steam engine, complete...	7 tons.	Engine	6 tons.
Boiler	9 „	Fuel, water,	
Fuel	4 „	and tanks..	4½ „
	20 „		10½ „

Oil Engines for the Navy.—Much that I have said in the last portion of this paper applies equally well to the Navy, but in one important particular the needs of the Navy are very different to those of the merchant service. Except in times of war, which, fortunately, seem to be few and far between, or when on special service, a cruising speed is all that is required, which, in round figures, means going about half speed on one-quarter of the horse-power, the engines then working at a very low efficiency. The difficulties previously mentioned as to the larger sizes of ships are the same here, and though we cannot now supply engines for these, what we can do, and do well, is to give an auxiliary engine for her cruising speeds. The total horse-power would remain the same, but would be divided up between the three engines, and I believe some experiments are now being carried out on these lines.

This combined system would give increased reliability, which is of absolute vital importance not only to the ship but to the nation, and the question of possible coal strikes would be less serious. There would be at the same time an economy in space and weight due to the displacement of boilers, and the ordinary objections to oil engines could no longer exist. The saving in fuel costs at cruising speeds would probably amount to at least 50 per cent., which, in a 12 months' fuel bill, would amount to a very large figure, part of this saving being due to the increased economy of the oil engine as compared with steam, and part to the very low efficiency of the steam engines when working at quarter loads. Each ship would have two entirely independent units of power, and either could be used separately or both together when the maximum power was required. It is gratifying to know, and it is a sign of the new era, that at last a Royal Commission has been appointed to investigate these matters, and it is to be hoped that the more difficult problem mentioned in the terms of reference as to the applications of oil for internal-combustion engines will receive the serious attention it demands, as being much more novel than the simpler problems as to the use of oil fuel.

THE SELECTION OF AN ELECTRIC FAN.

BY H. M. SCHEIBE.

FAN motors are so generally used and operate with so little attention that it is commonly thought that all fan motors are more or less alike, and that little care is needed in their selection. Examination, however, of the various fan motors on the market indicates that there exists a wide difference, not only in fans of different manufacture, but at times between different sizes and models from the same factory. The selection of a fan is made by two classes of purchasers, namely, the dealer who purchases in quantity from the factory and the user of the fan. As it is usually to a dealer's advantage to handle one line of fans exclusively, it follows that he should make his selection of that line with due regard to the customers' requirements. The following description will therefore treat the subject only from the standpoint of the user.

As in the case of larger apparatus, a fan motor should be selected with a view to the service which it is to perform as well as its initial and ultimate cost, and the service requirements should govern as to the size and type which is chosen. Portability, durability, cool running, and adjustability should be insisted on. Neatness of appearance and variety of finish will also appeal to the purchaser, especially when the fan is for use in the home.

The item of first cost ordinarily enters but slightly into the selection of an electric fan, as the prices of small fans of different manufacture are approximately the same. A slight difference in price should not, moreover, be given too great consideration, as it may be that the more efficient fan will easily save the difference in price during a single season. Usually the one question which arises at this point is whether the fan should be purchased. For residence purposes this is simply a question of whether the convenience is worth the price. For office or factory use the question of greater efficiency of the workers on account of more comfortable surroundings is the determining factor.

Operating Costs.—A few years ago fan motors were crude, clumsy, and inefficient affairs, but active development by the various makers has resulted in great improvement. There still exists, however, sufficient variation to make a difference in operating costs, in some cases of as much as 10 per cent. of the first cost of the fan during each season. This saving represents a good investment of the time required to make a careful selection. It is worth while for dealers to check up the power consumed both by the fans they handle and also by fans of other types. No special apparatus is necessary to make input tests other than a low-reading wattmeter and a voltmeter. It is, of course, evident that all fans which are tested on the same circuit should be of the same rated voltage, as a fan which is designed for a lower voltage will take a

larger current and deliver a greater volume of air than a fan built for a higher voltage.

Air Delivery.—It must not be assumed that a fan with low current consumption necessarily delivers less air than one with a larger input, as a wide difference will be found, both in efficiency of fan motors and in the efficiency of blades of different designs. A final judgment of a fan performance involves, of course, checking its air delivery against the power it consumes. Absolute air measurements cannot be made without special equipment and elaborate tests—and are at best of little interest to the fan user, who is concerned only with comparative results. It is easy, however, to select the better of two fans in point of air delivery by either of two simple methods that can be used almost anywhere. It is suggested that dealers in fans will find it to their advantage to be in a position to make these simple tests at any time, not only in order to select the best fan to handle, but also to be fortified with first-hand information on the apparatus that they sell.

The first test consists in placing the fan so that it will deliver a current of air exactly in a vertical direction. It should then be weighed on any ordinary scales graduated to ounces, first with the fan running at full speed, and again at a standstill. The difference in ounces represents the thrust with which the fan propels the air. Obviously only fans of the same blade diameter and same rated voltage should be used.

Another method, which is somewhat more direct, consists in placing the two competing fans face to face, about 6in. apart, with the shafts in line with each other both vertically and horizontally. A piece of cardboard large enough to more than cover the whole face of the fan blades is held loosely by the top edge midway between the blades. With both motors running at full speed the card will swing toward the fan with the smaller air delivery. Care should be taken that the card is held midway between the blades, and not necessarily midway between the guards.

It is evident that an electric fan which is used for cooling purposes should not become excessively warm itself. Practically all fans on the market will operate continuously at a temperature very much below that required to injure the insulation. Other things being equal, a fan of lower operating temperature should be selected, as low temperature means low losses in the motor or a large current of air passing the motor, both of which features are desirable.

Noise.—A certain amount of humming is involved in the operation of any electric fan. Where slight noise is not objectionable and maximum movement of air is desired the ordinary 4-bladed fan is to be recommended. If quietness is the prime consideration a 6-bladed fan running about two-thirds as fast should be selected. All of the leading fan makers now offer such a fan for residence use. A great deal of difference exists in this respect, however, between different makes of fans, as by properly shaping the blades some manufacturers have been able to secure much more quiet operation than others without sacrificing air delivery.

Ready portability of a fan is obviously desirable. This means that it must be light of weight without sacrificing stability, and sufficiently rugged to withstand careless handling and carrying by the guards. A marked advance in portability has recently been made by the introduction of pressed-steel motors. This construction has obvious advantages in point of light weight, neatness, and ruggedness. At the same time, the smooth, close-grained metal surface lends itself to a variety of ornamental plated finishes not readily applied to cast iron.

Durability.—Practically all of the large manufacturers of fan motors are now marketing apparatus that will operate satisfactorily under long continued periods of service. Probably no other class of rotating machinery receives less care and gives more uniformly satisfactory service than does the average fan motor. This statement is not necessarily true, however, of mechanically oscillated fans, as the oscillating mechanism necessarily involves a gear and link system, and the various types on the market differ widely in durability and in the facility with which wearing parts may be replaced. A link system that involves a long series of pin joints is very liable to develop lost motion rapidly and this makes the oscillation short and unsteady, when the mechanism begins to wear. Gears should be few in number and readily replaced without using tools other than the ever-present screwdriver.

All fan motors should be given periodic cleaning and lubrication, although many of them seldom get it. This is very important if long and satisfactory service is expected.

Adjustability.—Convenience demands that a desk fan be readily adjustable as to direction of air delivery and speed control. The fan should always be stable on the desk when pointing in any ordinary direction, and it should be capable of being mounted on the wall if desired without using extra parts or tools. In the case of oscillating fans it is convenient to be able to start or stop the oscillation without stopping the motor.

Inasmuch as some of the foregoing considerations are to a certain extent conflicting, it is necessary to decide which features are of paramount importance. Thus too low first cost is not compatible with highest quality. Effective air delivery is difficult to secure without a certain amount of noise. There is no reason, however, why neatness of appearance, light weight, &c., should not be combined with low power consumption and adequate air delivery.

A fan motor should be selected to suit the service conditions just as much as a large piece of apparatus. For instance, a 16in. fan delivers a big breeze sufficient to circulate the air in a large office, but most fans of this size, when running at high speed, are entirely too noisy for use in a house or quiet private office. A 12in. fan is usually adequate to any demand of house service, and several makers are marketing a special 6-bladed slow-speed fan of this size especially for residence use where noise is very objectionable. The 8in. fan is also largely used as a residence fan, as it is very easily carried about and entirely adequate where large volumes of air are not needed.—"The Electric Journal."

MINERS' SAFETY LAMPS.

As the result of experience gained by tests carried out at the experimental station of the Explosions in Mines Committee at Eskmeals, the departmental committee appointed by the Home Office have issued a report detailing the nature of the tests which in their opinion miners' safety lamps should pass in order to be admitted to the list of "approved" lamps in accordance with section 33 of the Coal Mines Act, 1911. The tests for flame safety lamps are included under three heads: (1) Mechanical tests, (2) photometric tests, and (3) tests in an explosive mixture. The mechanical tests include three: (1) dropping the lamp, complete with its glass, from a height of 6ft. upon a wooden floor five times in succession. A different glass is to be employed each time, and not more than one broken glass is to be permitted in the five tests. If two glasses break the lamp is to undergo five more tests, and if the glass breaks in two of these it will be held to fail. (2) Dropping a weight of 5lbs. from a height of 6ft. vertically upon the lamp. If the glass is cracked the test is to be repeated twice, when one failure will condemn it. (3) Dropping a 10lbs. weight, attached to a cord, from a height of 6ft., the other end of the cord being secured to the bottom of the lamp, which is suspended at a height of 7ft. from the ground. This latter test is proposed in order to test the security of the attachment of the different parts. Two further tests are also proposed for the lamp glasses separately. The committee consider that the minimum candle power to be required of flame lamps should be 0·30 c.p. (pentane standard), and that they should give this minimum for 10 hours. In the explosion tests the lamp is to have its behaviour tried first in a still inflammable atmosphere and then in horizontal and inclined currents in an explosive mixture at a maximum velocity of about 1,200ft. a minute. Each test is to last two minutes, and an ignition is to constitute a failure to pass. The mixture is to be, within limits, the most explosive obtainable with the particular combustible gas or vapour employed. The committee are of opinion that all approved lamps should ultimately have double gauzes of steel or best charcoal annealed iron wire (or copper wire in the case of those used for surveying purposes) of 28 B.W.G. with 28 meshes to the lineal inch. In the case of electric safety lamps it is recommended that only the first of the mechanical tests be required, the test being carried out with the battery removed and a dummy of the same weight substituted. The lamp should be required to give not less than 1½ c.p. after 10 hours' use, and as regards the danger of causing explosion, it should be tested by having the light switched on and off while it is in an explosive mixture.

STRUCTURAL STEEL FOR BRIDGES, &c., AND GENERAL BUILDING CONSTRUCTION.

A NEW edition of the British Standard Specification for Structural Steel for Bridges and General Building Construction (Report No. 15, revised August, 1912) has recently been issued. The new issue is of importance in view of the fact that the London County Council (General Powers) Act, 1909, requires that all rolled steel used in the construction of skeleton framework for buildings shall comply with the requirements of this specification. Since its first issue in June, 1906, the committee from time to time had brought before them points which had arisen in connection with its use, and the present issue embodies the necessary amendments in regard to these. Some of the more important modifications to the specification are as follows:—

(1) The classification of the material dealt with into two categories, A steel and B steel.

(2) The increase of the allowable phosphorus content in B steel from ·07 to ·08 per cent.

(3) The increase of the upper limit of tensile strength for plates, sections, and bars (other than rivet bars), from 32 to 33 tons per square inch.

(4) The reduction of the lower limit of tensile strength for rivet bars from 26 to 25 tons per square inch.

(5) The insertion of clauses dealing with (*a*) tests by an independent expert; (*b*) rejection after delivery; and (*c*) arbitration in cases where this is not otherwise provided for.

The price of the Specification is 5s. 2d. post free, and it may be obtained from any bookseller or direct from the offices of the committee, 28, Victoria Street, Westminster, S.W.

MISCELLANEA.

Flywheel Burst.—The flywheel of a Diesel engine installed in the electric light station at Maidenhead burst on the 5th inst., resulting in one man being injured and a portion of the building being wrecked.

To Raise Sunken Submarines: Admiralty's New Salvage Boat.—Messrs. Vickers have now completed, for the British Admiralty, a craft by which a sunken submarine can be lifted from the bottom and taken into dock. This is done in this way: The salvage boat floats immediately above the submarine, chain slings are passed round the sunken craft, and by means of two capstans on the salvage boat the submarine is hauled up right into a specially-constructed bottom in the salvage boat. The craft is 160ft. long, can lift 1,200 tons, and cost about £40,000.

The Prospects of the Gas Turbine.—Speaking in the engineering section of the British Association, Dr. Dugald Clerk, F.R.S., remarked that the efficiency of the gas turbine was so small that he did not think it could come into practical use for some time. As the horse-power went up the increase in weight was so enormous as to make it at present quite inefficient. It was stated, however, on behalf of Mr. Ferranti, the President of the Institute of Electrical Engineers, that he was making experiments which he hoped would improve the outlook of the gas turbine, though a more definite statement could not at present be made.

A Large Electrically-propelled Lake Steamer.—There is now under construction at the yard of Messrs. Swan, Hunter, and Wigham Richardson, Wallsend-on-Tyne, a vessel of 2,400 tons gross deadweight capacity on a draught of 14ft. for use on the Canadian lakes, which is to be fitted with the apparatus designed by Mr. Henry A. Mavor, of Messrs. Mavor and Coulson, Glasgow, and already tried on the small experimental vessel "Electric Arc." The machinery will consist of two 300 h.p. high-speed Diesel engines, each with its own alternating-current generator and exciter. On the propeller shaft just ahead of the thrust block there will be fitted the special compound wound squirrel-cage induction motor, turning the usual form of lake propeller at about 80 revs. per minute, as compared with the 400 revs. of the Diesel engines. A very simple arrangement of switches controls the flow of current in slowing or reversing, with a certainty of response quite impossible on a direct Diesel engine drive. The advantages derived from this arrangement in the numerous locks which have to be negotiated in the St. Lawrence and Welland Canals are expected to prove most important.

Distance Traversed by Steamer after Stopping and after Reversing the Engines.—The results of some experiments with the steamship "Flandre" to ascertain the distance travelled after stopping and after reversing the engines are recorded by E. Bertin in "Comptes Rendus de l'Académie des Sciences." With the engines stopped, the vessel reduced its speed from 4·5 metres to 2 metres per second in a distance of 900 metres. This result supports the author's formula: $x = 141 \cdot 9\, P^{\frac{1}{3}} \log_e v$, where P = displacement of vessel, x = distance traversed, V = the initial speed, v = the final speed. Applying the formula to a vessel of 20,000 tons displacement, and assuming V as 10 metres per second (19·4 knots), v as ·5 metre per second (1 knot), then the distance traversed is 5,011 metres. If the engines are reversed, the author obtains the following formula for reciprocating engines: $D = 10 \cdot 3\, P^{\frac{1}{3}}$; or, taking the usual relation between the distance traversed (D) and the length of ship (l), it becomes $D = 1 \cdot 6 l$. This formula, for steam turbines, is given as $D = 3 \cdot 2 l$.

Prizes for Military Aeroplanes.—The Secretary of the War Office announces that the Army Council has decided, on the recommendation of the committee of judges, to make the following award of prizes in connection with the recent military aeroplane competition: "A" prizes, open to the world for aeroplanes made in any country—First prize, £4,000, to S. F. Cody for Cody biplane (British) (No. 31); second prize, £2,000, to A. Deperdussin for Deperdussin monoplane (French) (No. 26). "B" prizes, open to British subjects, for aeroplanes manufactured wholly in the United Kingdom, except the engines—First prize, £1,000, to S. F. Cody for Cody biplane, No. 31. As no other British aeroplane completed all the tests, the two second prizes will be withheld, but the three third prizes of £500 each are awarded to the British Deperdussin Company, Ltd., for Deperdussin monoplane (No. 21), the British and Colonial Aeroplane Company, Ltd., for Bristol Monoplane (No. 14), the British and Colonial Aeroplane Company, Ltd., for Bristol Monoplane (No. 15). The following competitors whose aeroplanes were submitted to all tests, will receive £100 in respect of each aeroplane: M. Ducrocq, for Hanriot monoplane (French), No. 1; M. Ducrocq, for Hanriot monoplane (French), No. 2; the Aircraft Company, Ltd., for Maurice Farman biplane (French), No. 22; L. Bleriot, for the Bleriot monoplane (French), No. 4; L. Bleriot, for the Bleriot monoplane (French), No. 5; A. V. Roe & Co., Ltd., for Avro biplane (British), No. 7.

Improved Super-Dreadnought Battle-ship.—Immediately after the super-Dreadnought battle-ship "Iron Duke," now building at Portsmouth, is named and launched on October 12th, the building slip will be prepared for laying down another ship. This, it is understood, will be of even larger dimensions than the "Iron Duke." It is stated that the new vessel will be 700 feet long, and that she will have a total displacement of 30,000 tons. For propelling high-powered geared turbine engines are to be used, and these are calculated to give a speed of 29 knots. Her guns will probably be 14in. weapons, an advance on the present 13·5in. guns of the super-Dreadnought type. Ten of these will comprise the main armament, the guns being mounted in pairs in barbettes in such a way that an all-round fire can be maintained. The heavier guns and mountings will necessitate increased displacement, and, as the weapons will be longer than those now in use, the length of the ship must be correspondingly increased, and the power of the turbine engines enhanced. It is understood that while the side armour will be heavier the armour will be extended, to give more adequate protection against attacks from above, the advance of aviation having shown that danger from dropped bombs must be anticipated, and that not only gun positions, but the broad funnel openings leading to the furnaces and engine-rooms need to be screened. This will be a feature of the new design, and probably also steps will be taken to give better protection against aerial attack in case of vessels completing and already in commission. The new ship will be laid down about Christmas, and will be required to be completed within two years.

INDUSTRIAL AND TRADE NOTES.

Copper Production in Japan.—The Belgian Consul at Yokohama reports that the total production of copper in Japan in 1911 amounted to 51,708 tons, valued at £2,640,000, being an increase of 2,562 tons over the production in 1910, and an increase of 13,734 tons as compared with 1909.

Petroleum Production in Roumania.—An Italian consular report from Bucharest states that the production of crude petroleum in Roumania during 1911 amounted to 1,544,072 tons, showing an increase of 191,665 tons, or 14·17 per cent., on the output of the previous year, which was 1,352,407 tons.

Admiralty Oil Fuel Contracts.—The four principal Scottish mineral oil refining companies have secured from the Admiralty contracts for the supply of fuel oil aggregating 200,000 tons. The contracts have been allocated among the companies in proportion to their production. The price paid is a satisfactory one, being equivalent to 2¼d. per gallon.

Light Railway.—The Board of Trade have recently confirmed the undermentioned Order made by the Light Railway Commissioners: Birmingham Corporation Light Railway Order, 1912, authorising the construction of a light railway in the city and county of Birmingham, in the county borough of Smethwick, and in the urban district of Oldbury, in the county of Worcester

Personal.—Mr. R. R. Bevis has, we learn, resigned his position as managing director of the shipbuilding and engineering works of Messrs. Cammell, Laird, & Co., at Birkenhead, but will retain his seat on the board. Mr. Bevis was formerly with the old company of Laird & Co., and has been managing director at Birkenhead since the amalgamation of the two concerns.

Hours of Winding Enginemen.—The Home Secretary has issued a copy of a draft of regulations which he proposes to make under Sections 57 and 86 of the Coal Mines Act, 1911, with regard to the hours of employment of winding-enginemen. The regulations in question deal with the circumstances in which this class of mine employés may be employed over the statutory eight hours per day.

Wireless to Norway.—The Norwegian Government has entered into a contract with the Marconi Wireless Telegraph Company, Ltd., for the erection of high-power stations in Norway and the vicinity of New York, for the purpose of conducting a commercial telegraph service between Northern Europe and America. The contract made is for 25 years, with the option of renewal by the Norwegian Government. The stations are to be completed within 12 months of the foundations and buildings being ready.

Lock-out at a Tube Works.—Messrs. Stewart & Lloyd on Saturday last posted notices at the Phœnix Tube Works, Glasgow, intimating that they had been reluctantly compelled to close their works temporarily, owing to the continued sectional strikes and consequent dislocation. Fully 2,000 men are locked out. The trouble is largely confined to the galvanising and fitting-makers' departments. Recently an advance of 2s. was granted, but the men insisted on 4s. The operatives affected are mostly unskilled, but all classes are locked out.

Cheap Coal from Nova Scotia.—An owner of large coalfields in Nova Scotia has, it is stated, offered to supply the South Metropolitan and the Gas Light and Coke Companies with all the coal they require at a less price than they are now paying for North of England coal. In the last half-year the Gas Light and Coke Company used 887,877 tons of coal. The price they pay at present is said to be 12s. 4¾d. per ton, delivered in the Thames. The South Metropolitan Gas Company pay slightly more. During the last six months for which a report is available they spent £110,000 upon coal.

Russia's Oilfields.—In a current report to Washington the American Vice-Consul at Batum, South Russia, says: "On February 1st of this year 4,284 oil wells existed in the Baku districts. Of these 2,322 were producing. There are 139 big oil firms, with capital ranging from £51,500 to £2,600,000. In addition there are about 50 firms working by hand shallow wells, 50ft. to 100ft. deep. The depth of the large wells runs from 1,750ft. to 2,800ft., the average being about 2,100ft. The oil is mostly procured by bailing with buckets holding from 10 to 30 poods (pood=36·112lbs.). The Baku area consists of three fields, all either on the outskirts of the city or within a distance of a few miles."

Reduction in Cable Rates.—As a result of representations made to the Western Union Telegraph Company by the Postmaster-General of Great Britain and the Postmaster-General of Canada, reductions will be made on an early date, to be subsequently announced, in the rates for telegrams in plain language transmitted by that company and its associated companies between the United Kingdom, on the one hand, and Canada and the United States, on the other hand. The existing rate of 6d. per word for telegrams, subject to possible delay of 24 hours, will be reduced to 1½d. per word, and telegrams will be transmitted and delivered subject only to such delay as is necessary to give priority to ordinary traffic at 1s. per word. The new service of night letters will be brought into force at a charge of 3s. per 12 words and 2½d. for each additional word.

Steam-engine Makers' Society.—The report of the Steam-engine Makers' Society for September states: "Following upon the very satisfactory position in the full employment of our members in all parts of the country, as set forth in our last report, we are pleased to note this month's returns are still more satisfactory, and clear vacant books throughout the country is the rule rather than the exception. We may here observe that so good has been the demand for the services of the members of the S.E.M.S. that in many instances we have been unable to take full advantage of our opportunities, and this is especially so in relation to the services of skilled turners, more of whom we should like to see in our ranks. Our latest returns to hand show our unemployed to be only 62 out of over 15,000 members, compared to 127 unemployed as per last month's report, and 148 a year ago. Figures like these will require some beating."

Civil Liability of Trade Unions.—A Bill, entitled the Trade Disputes Law (Amendment) Bill, has been introduced into the House of Commons by Lord Robert Cecil in respect to the civil liability of trade unions for trade disputes. In a memorandum attached to the Bill it was stated that it proposed to restore the civil liability of trade unions in respect of tortious acts committed under their express sanction or recognition. It is proposed, however, to exempt from civil liability arising out of a trade dispute such part of the funds of a trade union as may be specifically allocated to provident purposes. With this object in view, the Bill empowers a registered trade union to set apart a provident fund, the accounts of and dealing with which will be kept distinct from those of the general or "trade" fund. The memorandum adds: "For the absolute immunity from civil liability conceded by the Trade Disputes Act, 1906, to persons who induce others to break a contract of employment, the Bill substitutes a limited immunity which will take effect in one case only, namely, where the person who is induced to break his contract of employment was a free labourer whose contract was entered into for the purpose of assisting one of the parties to a trade dispute." The Bill also provides for regulation of peaceful picketing with respect to the numbers engaged, the place where it takes place, and other matters. It is proposed to add a new sub-section to the Trade Disputes Act to the effect that it shall not be lawful for any person to engage in peaceful picketing unless he is wearing a badge showing conspicuously the word "picket," and, where he is acting on behalf of a trade union, the name of that trade union.

Purchasing Coal by Specification.—Over one million tons of coal was purchased last year by the United States Government, on specifications prepared by the Bureau of Mines. The advantages of purchasing coal under specifications are summarised in a report recently issued by the Bureau as follows: (1) Bidders are placed on a strictly competitive basis as regards quality as well as price. This simplifies the selection of the most desirable bid and minimises controversy and criticism in making awards. (2) The field for both the Government and the dealers is broadened, as trade names are ignored, and comparatively unknown coals offered by responsible bidders may be accepted without detriment to the Government. (3) The Government is insured against the delivery of poor and dirty coal, and is saved from disputes arising from condemnation based on the usual visual inspection. (4) Experience with the old form of Government contract shows that it is not always expedient to reject poor coal because of the difficulty, delay, and cost of removal. Under the present system, rejectable coal may be accepted at a greatly reduced price. (5) A definite basis for the cancellation of the contract is provided. (6) The constant inspection and analysis of the coal delivered furnishes a check on the practical results obtained in burning the coal. (7) Being paid for on the quality basis incites the contractor to prepare the coal more carefully. In the purchase of coal according to its heating value in order to award a contract properly, the proposals are reduced to a common basis for comparison. The method is to adjust all bids on a given lot of coal to the same ash percentage, by selecting as the standard that proposal which offers the coal containing the lowest percentage of ash. Each 1 per cent. of ash content above that of this standard is assumed to have a negative value of 2 cents a ton, the amount of the penalty which is exacted under the contract requirements for 1 per cent. excess of ash. The proposal prices are all adjusted in this manner, and are so tabulated. On the basis of the adjusted price, allowance is then made for the varying heat values by computing the cost of 1,000,000 B.Th.U. for each coal offered. In this way the three variables—calorific value, percentage of ash, and basic price per ton—are all merged into a single figure—the cost of 1,000,000 B.Th.U.—by which one bid may be readily compared with another.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

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Soldering irons. Hutton. 28001.

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Cupolas. Barnes. 282.
Balanced valve for controlling steam in locomotives. Evans, Robson, & Lewis. 288.
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Apparatus for operating the stop mechanism of colliery winding engines. Shrigley. 4941.
Tool turret for lathes. Berthet. 5730.
Lubricators. Johnston. 7131.
Pumps for gases. Siemens-Schuckerwerke Ges. 7663.
Nut locks. Taylor. 8670.
Arrangement of the tank or reservoir for fuel injection air in combustion engines. Romanowsky. 10145.
Air compressors. Milne, McCracken, & Graham. 11312.
Railway rail joints. Leonard & McMennamy. 13163.
Annealing pots. Thomas, and Thomas & Davies. 14598.
Water tube steam generators. L. & C. Steinmüller. 16058.

ELECTRICAL, 1911.

Wiring of contacts of telephone switches. Western Electric Company, Ltd. 16868.
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Telegraph instruments. British Insulated and Helsby Cables, Ltd., and Moore. 19065.
Regulators for electrically-driven ring spinning and doubling machines. Siemens Bros. Dynamo Works, Crowley, and Gowan. 19084 and 19085.
Electric battery lamp. Van Raden & Co., and Metz. 19194.
Arc lamps. Tate & Monkhouse. 19312.
Holders for incandescent electric lamps. Julius Sax & Co., and Collis. 26601.
Sparking plugs. Nagel. 27150.
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Electric fuses. Peard. 28872.

1912.

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Sparking plugs. Koutkine. 6062.
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TUESDAY, SEPTEMBER 10TH.

Aluminium ingot	80/- per cwt.
" wire, according to sizes, &c. ......from	102/- "
" sheets " " ...... "	120/- "
Antimony .... £28/-/- to	£28/10/- per ton.
Brass, rolled	$8\frac{1}{8}$d. per lb.
" tubes (brazed)	$11\frac{1}{2}$d. "
" " (solid drawn)	$9\frac{3}{4}$d. "
" " wire	$8\frac{5}{8}$d. "
Copper, Standard	£78/10/- per ton.
Iron, Cleveland	65/3 "
" Scotch	71/3 "
Lead, English	£23/-/- "
" Foreign (soft)	£23/10/- "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£8/5/- per bottle
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Spelter	£26/12/6 per ton.
Tin, block	£220/15/- "
Tin plates	15/- "
Zinc sheets (Silesian)	£29/17/6 "
" (Stettin; Vieille Montagne)	£29/17/6 "

Demand for Electrical Machinery in Spain.—According to the German Consul at Barcelona, there is a large demand in Spain for electrical apparatus, such as dynamos, motors, incandescent lamps, transformers, &c. There are, he states, excellent opportunities for doing business, especially in the case of the lighter machines weighing up to 8 cwts., as well as in the case of small electric fittings.

The Critical Velocity of Flow of Mercury in Small Tubes.—In the course of a paper on this subject, presented by Prof. E. G. Coker, M.A., before the British Association, the author stated that the flow of mercury in tubes at low velocities had been studied by Koch and others with a view to determining the viscosity at different temperatures, but no experiments appeared to have been made at high velocities at which the flow might be turbulent. In the present experiments both stream-line motion and turbulent flow were the subject of experiment in steel tubes having a range of bore from 0·04 cm. to 0·16 cm., and at temperatures between 0° C. and 100° C. The apparatus used was described in the paper and differed in some respects from that usually employed in viscosity determinations, particularly with respect to the method of maintaining a constant head of mercury and the measurement of the fall of pressure due to flow. The experimental values obtained showed that the flow tended to become unstable beyond a critical velocity depending on the bore of the tube and the temperature of the mercury. Although in general stream-line flow, in favourable circumstances, persisted beyond this critical limit, the lowest velocity at which turbulent motion might commence was found to vary inversely as the diameter of the pipe and directly as the viscosity.



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Power Transmission in Textile Mills.

THE development of the gas engine, oil engine, steam turbine, and electricity has within the present generation led to quite a revolution in many directions regarding the methods of producing and transmitting power. In numerous cases the advantages of one or the other have been so pronounced that the old-fashioned reciprocating steam engine has been completely displaced and there have not been wanting some who, in view of the rapidity with which such changes have been effected and the economies and advantages demonstrated, have predicted that the reciprocating steam engine would by the next generation only be found as a curiosity in museums. Threatened machines like threatened men have, however, a way of disconcerting their critics, and, while the advantages of many of its rivals may be readily admitted, experience tends to show that the reciprocating steam engine is far from the end of its career. But in view of the inroads made upon its supremacy it was hardly to be expected that the belief in its merits generally felt by those engaged in the textile industry should not be affected by the changes going on around them. The last few years have witnessed several inroads into this sphere of action by gas engines, steam turbines, and electricity, and as in the case of all innovations, the respective merits of the new methods have been proclaimed in rather a loud voice and with considerable persistency. The innovations have naturally led to a good deal of questioning, for the textile manufacturer is an alert individual and does not allow an advantageous opportunity to escape him if he can help it.

It will be remembered that a few years ago the question was taken up in the Yorkshire district and a committee appointed to investigate the matter, especially as regards the relative merits of electrical and mechanical driving, but the enquiry resulted in the expression of divergent views and left matters pretty much as they were. The taking up of the question by the Textile Institute was of course independent of this, but here again the question has proved a rather thorny

one. In the first place, a joint committee composed of Lancashire members of the Institution of Electrical Engineers and of the Textile Institute was formed to investigate and report on the best methods of driving, but as a result of adverse criticism on this procedure the Institute decided finally to appoint the committee itself. Four gentlemen were selected to set forth the respective merits of steam, gas, oil, and electricity. The writers of these several papers, though working conjointly as a committee, were in a sense advocates owing to their special experience, and to the fact that each one confined himself to the special features and advantages of one particular method of power production in textile mills. These four reports were presented for discussion to the meeting of the Textile Institute at Hawick last week. The relative advantages of the steam engine and the steam turbine were presented by Mr. G. B. Storie, of Rochdale, who, it may be remembered, read a paper on the application of the steam turbine to the driving of textile mills before the Manchester Association of Engineers several years ago. Gas power was dealt with by Mr. T. Roland Wollaston, who is associated with the Power Gas Corporation; oil engines by Mr. Frank Carter, of Messrs. Mirrilees, Bickerton, & Day, Diesel engine makers; and electrical power by Mr. J. F. Crowley, who is, we believe, connected with Messrs. Siemens Bros. At the outset of the investigation it was obviously impossible to discuss the questions involved unless a common power unit was adopted and here some little difficulty was experienced. Users of steam power speak and think almost universally in indicated horse-power and the indicator is equally as applicable to the gas engine and oil engine as it is to the steam engine, though for comparative purposes the brake or shaft horse-power, *i.e.*, indicated horse-power less engine friction, is not proportional to the indicated horse-power for any two engines, since the engine friction is more or less a constant quantity, irrespective of the load. Again, the indicator cannot be applied to ascertain the horse-power of a turbine, while further, electrical power, which may be purchased from an outside supply, is sold by the Board of Trade unit, while electrical engineers think and talk in kilowatts. For the purpose of making comparisons it was necessary for the authors to agree upon certain fundamental data, and the following was fixed upon: For good steam engine practice the relation of brake horse-power to indicated horse-power was taken as 9 to 10, for good gas engine practice as 8·5 to 10, and for Diesel engine practice as 8 to 10. The running hours per annum were taken as 2,750, interest and depreciation on engines, machinery, gas plant, &c., was taken at 10 per cent., and on buildings and foundations at 8 per cent. In considering labour charges, skilled engineers were taken at £120 per annum, mechanics and electricians £100 per annum, and labourers, firemen, &c., £65 per annum. For purposes of fuel costs, steam or bituminous producer coal was taken at 11s., anthracite at 32s., coke at 13s., and Diesel engine oil at 50s. per ton. These various arbitrary figures may not accord with individual cases or districts, but the conversion and adjustment for such departures is obviously easily made.

It was hardly to be expected that the four papers presented at the Hawick meeting, covering as they do so large a subject and involving so many complex questions, would receive adequate treatment in the course of a discussion immediately following their reading, and as a matter of fact very little that was pertinent was said, though it is to be trusted amends will be made for this in the course of the written discussion which is to follow and which will be published in due course. Pending this it may be permissible to offer a few observations on the papers themselves (abstracts of which we give elsewhere in this issue) and on the main questions involved. At the outset it will be evident that a comparison of the relative advantages of the various methods of developing and transmitting power in a textile mill, where the power plant forms as a rule only a small percentage of the total outlay of capital and continuity of running is essential, divides itself, roughly speaking, into three parts: (1) capital charges, depreciation, and running costs; (2) reliability; (3) quantity and quality of output. All three are finally expressed in terms of £ s. d. to the millowner, and it is their final sum which decides whether a given method is, or is not, advantageous to him. Economy of actual power production is but one aspect of a larger question, though the prominence given to it sometimes obscures the main issue. We may say at the outset that we hold no brief for either steam, gas, oil, or electricity, but we are concerned with the truth respecting the relative merits of each. A careful perusal of the papers, we must say, leaves us, as we venture to think it will most textile millowners, somewhat hazy as to where these lie, considering the question as a whole. At all events no particular one can claim predominance, and, notwithstanding the basic data agreed upon for the purpose of comparison, one puts the papers down, with a feeling that it is difficult to reduce the various questions involved to a common denominator.

The use of steam involves consideration of both the reciprocating engine and also of the turbine, and in the interests of the former it is to be regretted that its merits have not been set forth as explicitly and at as great a length as its rivals. Mr. Storie does profess to do this, but, with all deference to his efforts at impartiality, his paper leaves the impression that he is much more concerned to point out the merits of the steam turbine as the prime mover par excellence for large textile mills, as the other authors in turn point out the merits of gas, oil, and electricity than to put forward the strong features of the reciprocating engine. The reciprocating engine alone, in fact, amongst the various alternatives presented, appears to be without a special advocate. It may be the merits of this are so well known and have been so long tried that it requires no special advocacy. All the same we think it would have been better for purpose of comparison if they had been dwelt on at greater length. Mr. Storie's predilections for the turbo-alternator are pronounced and well known, and as impartial outsiders we cannot help feeling they lead him in some directions to rather prejudiced expressions of opinion. For example, alluding to the troubles and breakdowns due to failure of turbine blades, he states that "these defects have disappeared, and the systems of blading now used by the leading turbine builders are such that stripping of blades has almost become a thing of the past." This may be Mr. Storie's view, but it certainly does not accord with that of others. The chief engineers of the various engine inspecting and insuring companies, if they were at liberty to publish all they know about turbine breakdowns, could tell a different tale, and its bearing on the issue is obvious. Advocates of any innovation are proverbially enthusiastic, otherwise they would not deserve their position, nor would beneficial changes in many cases stand much chance of being instituted. The observant critic recognises this, and makes a discreet discount in arriving at his conclusions. It happens that at this early stage of development, the turbine, the gas engine, the oil engine, and electricity are fighting hard to dispossess the reciprocating engine from some of its long-established holding in textile mills, and their respective

advocates can scarcely avoid the instinctive tendency to paint their merits in rosy colours. The freedom of the steam engine's rivals from breakdown, which is illustrated in the several papers by some particular plant, is, we happen to know, not supported by the experience of insurance companies, who have very often to face the liabilities when breakdowns occur.

For the purpose of comparison Mr. Storie takes (1) a turbo-alternator, (2) an alternator driven by a horizontal cross compound condensing engine, and (3) a similar engine arranged for a rope drive, in each case for a power of 1,080 i.h.p. (750 kw.). On the basis of the figures given for depreciation, &c., he makes out the cost of (1) per indicated horse-power per annum £2. 4s. 4d., (2) £2. 10s. 8d., and (3) £2. 7s. 10½d. Between these various figures there is not much to choose, even with the assumptions made, though the slight advantage on the figures taken lies with the turbo-alternator. It should be pointed out, however, and this again shows the difficulty of making strict comparisons and how easy they may be misleading, that the losses between the engine and the machine drive are considerably greater with electricity than with ropes, probably to the extent of 10 per cent., and in an actual scheme would require to be taken into account. Mr. Wollaston, in presenting the case of the gas engine, puts it on the whole succinctly and fairly, and gives some interesting figures respecting an actual installation at the Hollins Mill, Marple, where the gas engine is worked in connection with an ammonia recovery plant, and on the basis of these deduces the cost per unit of power with an electric drive, and also works out similar hypothetical results for other power of gas-engine installations, for which we must refer the reader to page 359. Although the Diesel engine is undergoing rapid development, its application to the driving of textile mills is extremely limited. For one thing the engine so far has only been made in small sizes; at all events, for purposes of comparison only small sizes are taken. The economy of the Diesel engine as regards fuel cost is pronounced and unmistakable, but a reference to the figures given shows that other costs do not work out so economical, and it is in the smaller sizes that the Diesel engine excels when compared with its competitors, and we would add further that experience of Diesel engine breakdowns indicates that they call for superior skill and intelligence in their supervision than steam engines, while failures, if they do occur, are as a rule disastrous. Here, again, one touches upon the question of reliability, and detailed consideration of the various types of prime movers discussed shows that many items have to be considered in an actual power plant which are not taken account of in the papers before us. A pertinent illustration of this is afforded by the fact that under local by-laws it is often compulsory for the effluent from gas-cleaning plant to be filtered and deoderised before turning into drains. This, of course, entails labour and expense, though no account is taken of it by Mr. Wollaston in setting forth the merits of the gas engine.

The merits of electric driving for textile purposes is a matter round which a good deal of discussion has been waged, and about which no very clear conclusion can be said so far to have emerged. The advocates of electricity cannot, on the basis of capital charges and running costs, establish any strong claim for consideration in its application to powers below 500 kw., though in larger sizes turbo-alternators score largely. On behalf of electric driving a good deal is claimed in the way of superiority of yarn as a result of greater uniformity of speed, but much of this superiority appears to be based upon very delicate measurements and fluctuations within narrow limits, and in one or two instances where electric driving has been adopted we are informed that, as compared with pure mechanical driving under normal conditions, it is difficult to find an economical expression for this superiority when the yarn is sold on 'Change. Of course, it may be that this is only a partial opinion, and we trust in the written discussion further light will be thrown upon the point. That electric driving in several instances of power reorganisation where operations are conducted in several buildings has been economical and led to better spinning has been demonstrated and is easy to understand, but these cases are abnormal, and it is unfair to take such improvements as a standard for comparison with normal conditions. The fact is that the choice of a power plant, whether in laying out a new mill or reorganising an old one, depends largely on circumstances. In many cases the conditions are so complex that none but a well-trained engineering expert, free from prejudices and with no axe to grind, is capable of deciding which is best, and the four papers referred to confirm us in this opinion. They certainly do not show that the reciprocating steam engine is likely to be displaced in the textile industry to any serious extent, and though its merits are not so loudly proclaimed as those of the rival methods described, manufacturers will do well not to disturb existing arrangements or depart from established practice when new mills or alterations are under consideration without taking advice from some independent, impartial authority.

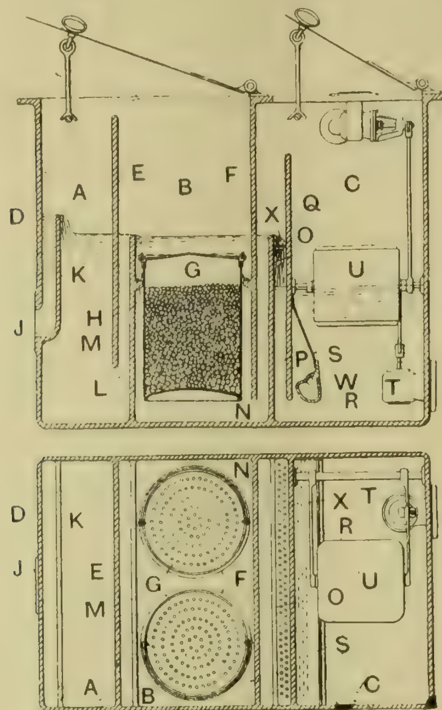
MORISON'S FEED-WATER HEATER AND FILTER.

WE illustrate herewith a design of apparatus for heating and filtering boiler feed water, the invention of Mr. D. B. Morison, Hartlepool Engine Works, Hartlepool. Referring to the illustrations, the water filtering compartment forms the central compartment B of a number of inter-communicating compartments A, B, and C into which the body D of the apparatus is divided by vertical partitions E and F. The filtering compartment is provided with two removable vessels G, vertically disposed and containing filtering material, the top and bottom of each vessel being perforated for the passage of the feed water through the filtering material. The compartment B is divided horizontally into upper and lower portions by a plate H, having two holes therein through which extend the filtering vessels G. With this arrangement it will be seen that when it is desired to remove one of the filtering vessels for cleaning or refilling, it can be easily lifted out of place and be replaced by another vessel containing new or cleansed filtering material, or if a spare filtering vessel be not available, the hole in the plate H can be closed by a cover plate so as to prevent short-circuiting of the water. Each filtering vessel is provided with means to admit of its being readily removed.

In some cases the filtering compartment may be subdivided into two or more smaller compartments, each containing one or more removable filtering vessels, the arrangement being such that any one of the compartments can be cut out of operation and the filtering vessel or vessels withdrawn therefrom as required, or the water filtering vessels may be arranged in series and it may be at different levels. Or one or more of the vessels may be adapted for the filtration of

very impure water, in which case one or more of the vessels may, for example, be extended above the normal water level and contain material suitable for the effective filtration of such impure water.

The filtering compartment B is in communication with a compartment in which the feed water can be heated, and also with another compartment through which the water



MORISON'S FEED-WATER HEATER AND FILTER.

flows before entering the filtering compartment, and which is suitably arranged for the collection of float oil. The water heating compartment is provided with a steam-heating nozzle. A is the compartment into which the feed water is delivered through an inlet J and over a weir K that promotes the collection of float oil in the compartment A the bottom of which is in communication through an opening L and a vertical passage M with the filtering compartment B at a part thereof above the filtering vessels G. The bottom of the filtering compartment B is in communication through upwardly and downwardly extending passages N and P, formed between the partition F and additional partitions O, Q, within the last compartment C which contains a steam nozzle or pipe R and also an outlet valve T controlled by a float U. The steam nozzle or pipe R is provided with an upwardly extending inclined plate S which is connected at the top to the adjacent side wall Q so as to form therewith a narrow chamber, the upper portion of the plate S having perforations therein through which the current of water set up by the jets of steam issuing from the apertures W of the nozzle or pipe R can pass, the perforated plate acting to facilitate effective condensation of the steam and to reduce surface agitation of the water in the compartment C.

The water outlet from the filtering compartment B is so arranged, as by making the partition wall O of suitable height, as to maintain a head of water above the filtering vessels G whereby a large surface of water is provided for the collection of float oil which can be removed from the apparatus as and when required, for example by closing the outlet from the last compartment C and raising the level of the water in all the compartments until the float oil can be drawn off through a suitable outlet. The communicating passage P through which the water flows after passing through the filters G is provided with a removable sieve or perforated plate X so as to prevent any loose portion of the filtering material, or other solid matter, passing to the feed pumps through the compartment C. When the steam available for heating the feed water contains oil, such uncleansed steam may be condensed by the feed water prior to passing through the filtering compartment, and the water may be further heated by pure steam after passing through such compartment.

SOME UNIQUE ELECTROMAGNETS.*

THE discovery of electromagnetism by Hans C. Oersted in 1820 must be ranked among the discoveries which are of the greatest importance to modern industry. Applications of the electromagnet are to be seen everywhere and in the most varied forms. Almost all of the familiar forms of electric apparatus involve the use of an electromagnet. This applies to the telegraph, telephone, dynamos, motors, transformers, electric bells, annunciators, control apparatus of almost every form, &c. The first electromagnet was made in 1825 by William Sturgeon in England. This form of magnet was further developed by Joseph Henry in the United States, and he, in 1831, made two magnets, each of which would lift about 3,000lbs., and was operated by a small battery. He also made a telegraph which could be operated from a distance, and even used an earth return, which has since become so common.

Since that time electromagnets have been made in all forms and sizes, and only a few of the more unusual forms can be mentioned here. The magnet giving the strongest field which had been made up to that time was constructed in 1894 by H. Du Bois, a professor in the University at Berlin, Germany. This magnet was constructed in the shape of a ring, around which the windings were uniformly distributed. This magnet enabled a field of 40,000 gausses to be obtained in the air gap, which was cut through at one portion of the ring.

The magnetic flux which can be obtained with any magnet depends upon the magnetomotive force and upon the reluctance. The magnetomotive force is proportional to the ampere-turns which link the magnetic circuit. It is sometimes expressed directly in ampere-turns and sometimes in gilberts, the gilbert being the unit in the C. G. S. system. The reluctance of a magnetic circuit depends upon the material of which it is composed. Iron and other ferro-magnetic

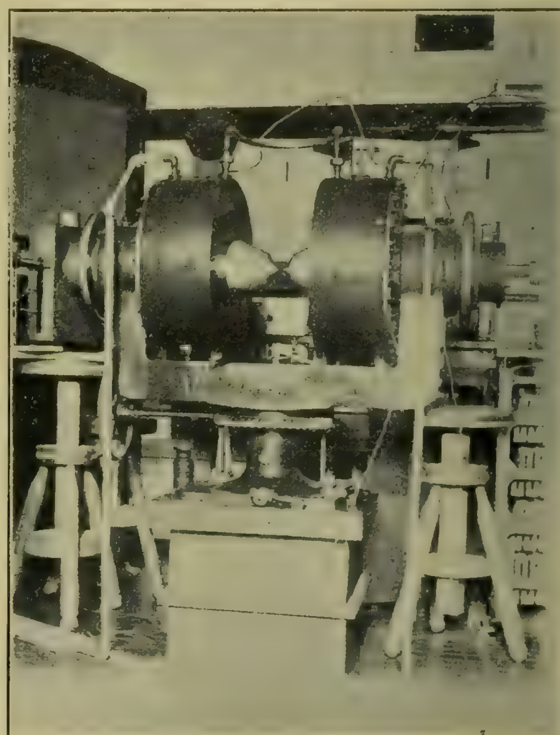


FIG. 1.—WEISS MAGNET AT U.S. BUREAU OF STANDARDS.

materials have a small reluctance and consequently an intense magnetic flux can be created in them. The reluctance is inversely proportional to the permeability of the material. The permeability of air and most other substances is one, while the permeability of iron sometimes reaches values of many thousands. The magnetic flux, which is obtained in any magnetic circuit, is directly proportional to the magnetomotive force and inversely proportional to the reluctance.

* From the "Electrical Review and Western Electrician."

The flux is measured in maxwells in the C. G. S. system, one maxwell being the same as what is sometimes loosely referred to as a line of force. The density of the magnetic flux is expressed in gausses, one gauss representing one maxwell per square centimetre. The greatest flux-density which has been obtained in air is in excess of 40,000 gausses.

Prof. Du Bois later made a commercial form of electromagnet for intense fields in the shape of a half ring. This consisted of a base plate weighing 40 kgs., and two arms in the shape of quarters of a ring, leaving a small air gap between their ends. Each of these arms was surrounded with four coils

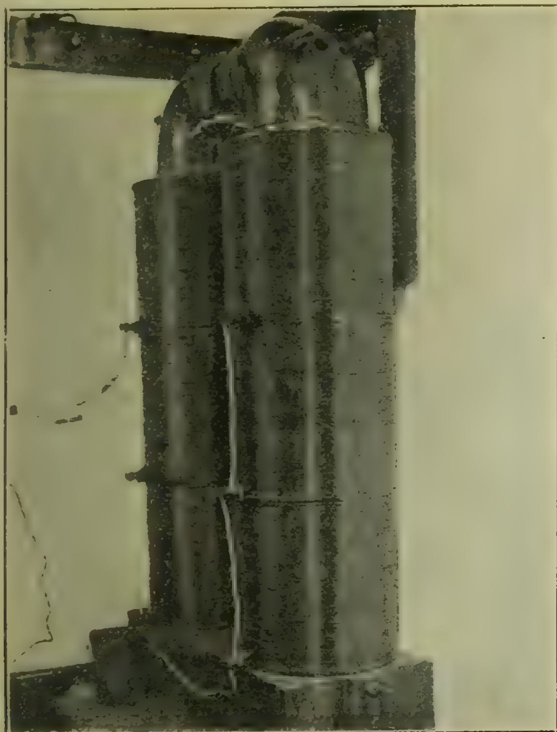


FIG. 2.—BRACE MAGNET AT UNIVERSITY OF NEBRASKA.

of wire, which, with the core, weighed 60 kgs. There was altogether 2,500 turns of wire. This winding would carry 20 amperes and with all the turns connected in series required 70 volts for its operation. With pole pieces having flat circular faces with a radius of three millimetres, and with an air gap of one millimetre, a magnetic field could be secured in the air gap having a flux-density of about 40,000 gausses, the same as with the ring magnet. The self-inductance of this half-ring magnet was 180 henries. This magnet was made by Hartmann & Braun, Frankfort, Germany, and a smaller size of the same design weighing 25 kgs. is also available. The linear dimensions of the latter are about one-half those of the larger magnet. These magnets were constructed in 1899, and up to that time were the most powerful electromagnets on the market.

By increasing the magnetomotive force which is applied to a magnet of appropriate shape, it might seem that there would be no limit to the strength of the magnetic field which could be produced. Practical difficulties, however, limit this, as the heat generated in the magnetising coils, if too large a current be used, causes difficulties. In order to overcome this objection a magnet was designed by Pierre Weiss, professor in the Polytechnic School of Zurich, Switzerland. In this magnet the copper coils which surround the core are immersed in an oil bath in which is a coil of pipe carrying a stream of cold water, so that the heat is carried off as fast as it is generated (see Fig. 1).

The yoke of this magnet is of extra soft steel bent twice at 90°, and to this are connected two cylindrical cores of the same material. These cores are 15 centimetres in diameters and 52 centimetres long. The yoke is 12 by 21 centimetres, and, consequently, has a cross-section of 252 square centimetres (4 sq. in.). The cross-section of the cylindrical cores is 176·7 square centimetres (2·8 sq. in.). The weight of these cores is 70 kgs. The coils are fixed in position, but the position of the cores can be adjusted by means of a screw so as to fix the air gap at any desired value. Pole pieces 13·5 centimetres long and tapered are attached to the cores. The copper conductor consists of strips 15 millimetres wide and one millimetre thick, wound in a spiral, with an insulation between turns 0·2 mm. in thickness. Each coil contains 15 spirals 3·5 mm. apart, and each spiral contains 112 turns. The total number of turns on the magnet is, therefore, 3,360. When the maximum current, 60 amperes, is flowing, this gives 201,600 ampere-turns. The resistance of the winding when cold is 4·9 ohms, and this is not increased more than 5 per cent. by heating. About 300 volts are required to give the maximum excitation, which, consequently, requires about 18 kws. In most of the experiments for which the magnet is used, however, 25 amperes is sufficient, the consumption then being only 3 kws. If a current of 50 amperes through this coil is suddenly broken, an arc 20 centimetres long is produced, owing to the high inductance of the circuit. As there is, of course, a possibility of this happening at any time, the oil insulation has an additional advantage in preventing the breakdown of the winding from this cause.

The total weight of this magnet is about 1,000 kgs. It is mounted on a pivot, so that it may be oriented in any position, the motion being controlled by means of a tangent screw. With 53 amperes flowing in the magnetising coils and an air gap of 1·95 mm. (0·0768in.) and pole pieces of the best extra soft steel, a flux-density was secured in the air gap of 46,250 gausses. With pole pieces of Swedish iron the flux-density was 45,900. By reducing the air gap slightly, a flux-density as high as 46,750 gausses was secured. The maximum intensity of magnetisation in the iron was 1,850 C. G. S. units. This magnet was constructed at the Oerlikon works. A duplicate of the original magnet was made for the Bureau of Standards, Washington, D.C. This is illustrated in Fig. 1.

One of the most powerful electromagnets which has been constructed in this country is that designed by the late D. B. Brace and constructed for use in the Physical Laboratory at the University of Nebraska, where Prof. Brace carried on important work in the investigation of magneto-optical effects. This magnet is shown in Fig. 2. The magnetic circuit was constructed of Norway iron, the cores being 8in. diam. and surrounded with six magnetising coils of No. 10 copper wire. These could be connected in any desired combination. The weight of the copper in these coils was about 650lbs., and the total weight of the magnet about 4,000lbs. Its height was about 4ft. A variety of pole pieces was available, giving areas of pole face up to 96 sq. in. With pole faces measuring 2·5in. square and an air gap of 2·09in. (5·3 centimetres) a strength of magnetic field of 8,700 gausses was obtained by using 100,000 ampere-turns. With conical pole pieces having a circular pole face of diameter 0·7in. and an air gap of 0·1in. (2·5 mm.), a flux-density in the air of 38,000 gausses was secured by using 66,000 ampere-turns.

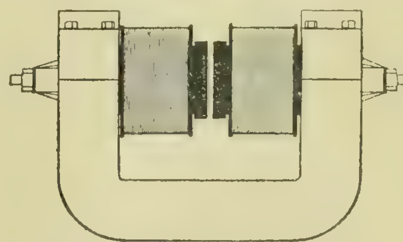


FIG. 3.

This current was kept on for two hours without undue heating. With the air gap increased to 0·25in. (6·5 mm.) a field of 30,000 gausses could be maintained indefinitely with 40,000 ampere-turns. This notable magnet is still in use in the new Brace Laboratory of Physics under the direction of C. A. Skinner, who is now the professor of physics.

Some of the most notable experiments in magnetism which have been made have been performed by B. O. Peirce, professor of natural philosophy in Harvard University. One of the magnets used by Prof. Peirce is represented in Fig. 3. This magnet has a frame of cast iron with a rectangular cross-section 20 by 40 centimetres (8in. by 16in.). The magnet cores are of soft steel and are cylindrical in shape, with a

diameter of about 10in. They fit very accurately into sockets in the frame. The pole pieces shown in the figure are 1·75in. thick. The exciting coils contain 2,823 turns, and have a resistance of about 12·4 ohms. The total weight is 3,300lbs. This magnet was designed by A. W. K. Billings to give a nearly uniform field of about 18,000 gausses throughout the whole air gap between the pole pieces.

The curve V W in Fig. 4 shows the total flux across the air gap when the excitation is about 5,700 ampere-turns. One division measured horizontally in this figure represents one centimetre and one division measured vertically represents 1,000,000 maxwells. The line M N is plotted from values which are proportional to the reciprocal of the total magnetic flux, and this is seen to give a line which is nearly straight. With an excitation of 28,500 ampere-turns, the total flux for different air gaps is shown by the curve P Q. The line of reciprocal value in this case is R S, which also appears to be a straight line. The fact that the lines M N and R S are straight is not a general condition for all magnets, but one which is peculiar to this magnet and depends upon the arrangement of the exciting coils on the core. The magnetic flux, which is considered in plotting these curves, includes only that which is between the pole faces and not any outside of this space. This magnet is supplied with two conical pole pieces giving a flat pole face with a diameter 0·57in. (14·5 mm.). With an air gap of 0·0545in. (1·38 mm.), the following values of the flux-density in the air gap were obtained:—

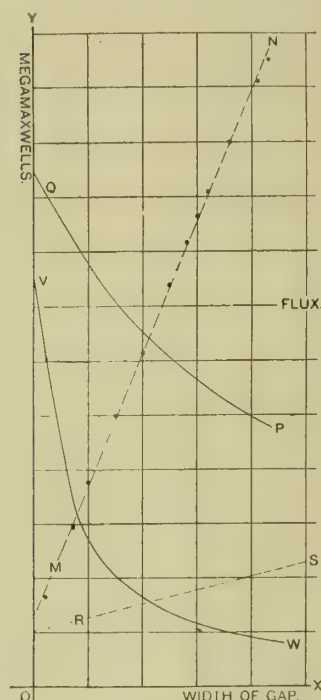


FIG. 4.

Flux Density in Gausses.	Approximate Number of Ampere Turns.
33,900	22,600
39,300	56,500
41,400	76,200
42,200	98,800

With a somewhat narrower gap and excitation of about 127,000 ampere-turns, the measured flux-density in the air gap was 43,160 gausses. The shape of the pole pieces here used was intended to give a uniform field and not maximum concentration. A more intense local field could have been produced with pole pieces having a sharper angle. It is to be noted that the area of the field here measured was more than 114 sq. mm. The excellent design of a magnet which will give such an intense field is made evident by the following quotation from Du Bois's "Magnetic Circuit in Theory and Practice," where it is stated: "A ring electromagnet of manageable size, with truncated conical pole pieces of 120° aperture, enables us to have fields up to, say, 40,000 C.G.S. units over an extent of some square millimeters. To exceed this to any material extent could at present be only accomplished by an undue expenditure of means out of all proposition with the end in view."

Electromagnets of various forms have been used for some time past in order to remove particles of iron from the eye. Prof. Haab, of Zurich, Switzerland, has designed a new type of eye magnet which is intended for physicians' use and has a number of improvements in its make-up, so that it is likely to be of better service in these very delicate operations than the ones which have been heretofore used. It is shown in Fig. 5. Dr. Haab finds that a magnet of this kind needs to have the greatest possible force in order to draw deeply embedded iron particles out of the eye. It should also be mounted conveniently in a horizontal position and have a foot switch so that the current can be applied while the operator is using his hands to manipulate the eye. Then the magnetic points must be of the right shape to suit the kind of operation which is carried out, and interchangeable pole pieces should be provided. Surgeons have sometimes found that a weak magnet fails just at the critical moment of the operation, and is not strong enough to draw out the iron particle, so that for this reason the present magnet is of a very powerful design. It is mounted on an iron column, with a shelf for placing the patients' arms in the best position. The magnet is designed so that the pole point is not too long to be strong, and at the same time magnet body does not hide the field of sight from the operator. Three forms of pole pieces are provided, as shown in Fig. 6. The other pole of the magnet is bell-shaped. This apparatus is made at the Oerlikon Works. This magnet exerts a greater force than any other which has been designed for this purpose. The coils of this magnet can be wound for voltages from 60 to 300 volts, and the maximum power consumed is 1 kw. The total weight of the apparatus is 286lbs.

One of the most important applications of electromagnets in industrial work is for lifting large masses of iron and steel. The lifting magnet has probably had a greater influence in reducing the cost of handling iron and steel than any other apparatus, except the travelling crane, with which it is, of course, used. The lifting magnet is used for handling pig iron, scrap, castings, billets, rails, and plates; for handling skull-cracker balls and for loading and unloading cars and ore vessels. It results in a great saving of time and labour, and consequently of cost in doing the work. The installation of lifting magnets at the works of the Carnegie Steel Company enabled two men to do the work formerly requiring 25 labourers, and altogether 28 men took the place of 350 labourers.

In unloading a steamship at Indiana Harbour, Ind., carrying 4,000,000lbs. of pig iron, unloading was accomplished by means of a lifting magnet in 10 hours and 30 minutes. Two operators did this work, with the assistance of two labourers for part of the time. Under the old methods of unloading, two days and two nights would have been required for this work, with the services of 28 men.


FIG. 5.—MAGNET FOR REMOVING PARTICLES FROM THE EYE.

Lifting magnets are usually circular in shape, one pole being formed at the circumference and the other near the centre. The coil carrying the current is placed between the two. Such magnets are made in sizes up to 62in. diam. The weight which may be lifted depends upon the shape and character of the material. One thousand pounds is an ordinary lift for one of these magnets, but under favourable conditions as much as 30 tons can be lifted.

One curious use which has been made of these lifting magnets is to salvage magnetic material immersed in deep water. The first application of this kind was in the Mississippi River at New Orleans, where a barge loaded with 1,500 tons of wire nails, hoops, &c., sank in 35ft. of water. These nails were recovered. The construction and insulation of the magnets used is such that they are waterproof and can be used for such work without injury.



Fig. 6. Forms of Pole Pieces.

Rectangular plate magnets are used for handling hot billets slightly below a red heat. The winding of the magnets is covered with asbestos insulation and is thus fireproof. Another unique form of lifting magnet is designed for handling 60ft. rails. It consists of two magnets mounted at the end of a beam. Nineteen rails, weighing 30,400lbs., were lifted at one time, and more than this number have been included in a single lift.

THE NEW GRAVING DOCK, BELFAST.*

Mechanical Plant and General Appliances.

BY W. REDFERN KELLY.

The new graving dock at Belfast is one of the finest and best equipped dry docks in the world at the present moment; and is indeed the only graving dock in which it is possible to place the leviathan steamer, the "Olympic," the world's largest existing specimen of naval architecture. It is not only famous for its huge capacity, but for its general equipment, which is of the most modern and up-to-date type. The Belfast Harbour Commissioners expended upon this great dock and its collateral works, a sum of £350,000. The works were commenced early in the year 1904, and the time required for their construction was about seven years. Although no formal or ceremonial opening of the new dock has as yet taken place, it was nevertheless commissioned for practical use on April 1st, 1911, when the S.S. "Olympic" was admitted for final fitting out purposes, a few weeks immediately prior to her departure on her maiden voyage.

The general dimensions of the dock, Fig. 1, are as follows: Length of dock, on floor, from the inner face of the caisson to the toe of the battered wall at the south end of the dock, 850ft.; or if the caisson be placed in its outer berth, about 887ft. Length, over all, that is, from the coping at the south end of the dock to the inner face of the caisson when in its outer position above the apron, at the entrance, 901ft. Breadth of dock, from toe to toe of the battered side walls, below the altar courses, 100ft.; from coping to coping, 128ft.; and at entrance, 96ft. Depth of surface of floor of dock, at its centre, below harbour datum (which latter is 1ft. 9in. below average low-water line), 26ft. 6in. Height of coping, above harbour datum, 16ft. Depth of floor surface (at its centre) below the level of the entrance sill, 2ft. Height of keel blocks above the floor, 4ft. 6in.; or without timber capping, 3ft. 6in.

Depth of water on keel blocks, at H.W.O.S.T. 32ft. 9in.
Depth of water on dock sill, at H.W.O.S.T. .... 35ft. 3in.
Width of caisson chamber, in the clear .... 23ft. 4½in.

* Abstract of paper read before the Institution of Mechanical Engineers, July, 1912.

The dock floor falls 12in. on either side of the centre line, towards the open drains at the sides of the dock, no longitudinal fall being given. The level of the surface of the inner and outer sills, at the centre, is 40ft. 6in. below coping line, or 24ft. 6in. below harbour datum. The level of the surface of the concrete apron, northward of the outer sill, is 43ft. 6in. below the coping level; or 27ft. 6in. below harbour datum. The level of the upper surface of the brickwork invert of the caisson chamber, and the caisson track, in the centre, is 45ft. 3in. below coping level, or 29ft. 3in. below harbour datum.

Pumping Appliances.— The capacity of the graving dock, below the level of high water of average spring tides, without making any allowance for displacement by a vessel placed in the dock, is about 21 million gallons of water; and the duty imposed upon the pumping plant is that of discharging this great quantity of water, within a period of not more than 100 minutes from the time of commencing the pumping operations. During this pumping period the tide outside the dock will usually fall to the extent of about 2ft.

The plant provided for the performance of the above work (see Fig. 2) comprises three main pumps of the centrifugal type, which are driven by three cross compound vertical engines. Each pump has two suction pipes, 42in. diam., and one delivery pipe, which tapers from 54in. to 60in. diam. The impeller, or pump disc, is 7ft. 6in. diam. The extreme depth of the pump casing is 12ft. 7⅝in.; and the over-all width of the pump is 12ft. 10in. The centre of the impeller disc is 18ft. 3½in.; and the top of the pump casing is 24ft. ½in. respectively, above the dock floor, close to the inlet to the pump well. The six large suction pipes are carried through the engine-room floor into the main sump underneath, their bell-mouthed ends reaching a level of about 6ft. 8½in. below the dock floor, close to the inlet, and 5ft. 3½in. above the floor of the main sump. The pipes are securely cement-grouted against the foundation brickwork through which they pass, and have thus been made perfectly water-tight. The pump bearings are of white metal, one on either side of the disc, and are each 3ft. in length. Each pump is fitted with a steam ejector, in order that the air can be exhausted in the pump casings and suction pipes, when restarting the pumps after their having been stopped, and when the water has been lowered a depth of about 4ft. in the dock. The discharge from the ejectors is led into the main pump discharge culvert. Each pump is also provided with a water gauge, to indicate when the pump casing is full. To each of the main pumps a sluice valve, 54in. diam., worked by hydraulic power, is fixed to the delivery branch, to which the main delivery pipe is bolted. These discharge pipes, three in number, are carried through the side wall of the engine and pump-room into the outlet culvert, through which the delivery is led to the tideway at the south end of Clarence Wharf. At the outer end of each delivery pipe a properly-balanced flap valve, of elm timber, known as a "foal's foot" valve, is fixed, and can be approached through a covered man-hole, just above the valve, outside the engine-house. For the purpose of dealing with any leakage, or drain waters from the dock culverts, which the main pumps cannot reach, an auxiliary pump has been provided. This pump has suction and discharge pipes, each 14in. diam. The diameter of the impeller, or pump disc, is 48in. The pump is driven by an inverted direct-acting compound cylinder engine.

There are, in all, for the main pumping (see Fig. 2) three cross compound non-condensing vertical engines, one set to each main pump, coupled direct. The cylinders of these engines are 22in. and 38in. diam. respectively, with a stroke of 20in.; they are capable of running at an average speed of 125 revs. per minute, and at this speed the engines run quietly, due to proper steam distribution and efficient balancing. They are designed to suit a working pressure of 160lbs. per square inch (100° superheat); and each set develops 741·5 i.h.p. at 121 revs. per minute. They are steam-jacketed around the top, bottom, and sides, and are covered with an asbestos non-conducting composition, and cased with steel planished sheets. A water service has been provided for all main bearings. The steam pipe range is of solid-drawn steel tubes throughout, with flanges riveted on, a large steam separator being placed at the bottom of the vertical pipe which leads from the boiler to the engine-house. Expansion in the pipe range has been so well provided for that there is no difficulty in keeping the joints tight.

The leakage pump is driven by a small direct-acting inverted cylinder cross compound non-condensing engine

coupled direct. This pump runs at about 300 revs. per minute, and is intended for the removal of such leakage water as may find its way into the dock after the main pumps have ceased to draw.

Among the various accessories to the pumping plant may be mentioned: A small duplex pump (Odesse type), with pump piston $2\frac{3}{4}$in. diam., and 4in. stroke, is fitted on the engine-room floor, for internal drainage purposes. An overhead travelling crane, worked by hand, and capable of lifting weights up to 7 tons, has been provided, and travels just below the roof.

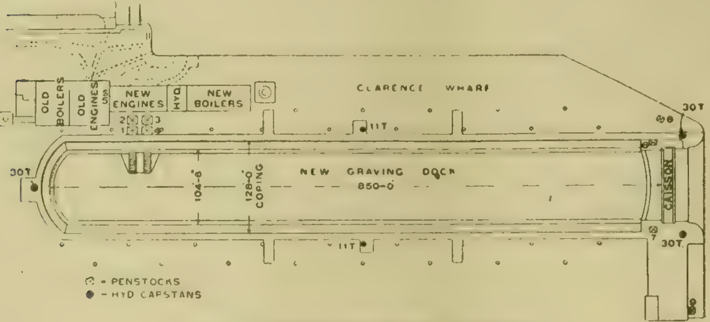


FIG. 1.—NEW GRAVING DOCK, BELFAST

An automatic water gauge, with vertical index board, has been erected in the engine-room, in order to indicate with facility the level of the water in the graving dock at any moment. It is constructed on a scale of half full size. The gauge is operated by a float, acting within a metal pipe, the latter being led to the bottom of the sump; and the float is placed in communication with the indicator by a cord of copper wire, led over reducing pulleys, and to which a pointer is suspended. The arrangement is an ingenious and convenient one, the gauge being visible from all essential points in the engine and pump-room.

The following are some of the leading figures for the pumping plant: Diameter of cylinders, 1ft. 10in. and 3ft. 2in.; length of stroke, 1ft. 8in.; diameter of piston rod, 4in.; diameter of shaft journals, $8\frac{1}{2}$in.; length of connecting rod, 4ft. 2in.; diameter of pump impeller, 7ft. 6in.; diameter of pump shaft, $8\frac{1}{4}$in.–$8\frac{3}{4}$in.; capacity of feed heater, per hour, 4,600lbs.; temperature of feed in degrees Fah., 200°; evaporation of boilers, per hour, 64,000lbs.

Hydraulic Power-supply Plant. — This plant comprises two sets of pumping engines and pumps, and a hydraulic accumulator, together with the requisite water pressure and return piping, and is utilised for the work of opening and closing the travelling caisson gate, the lifting and lowering of the nine penstock sluice doors, the working of the five hydraulic capstans, and also of the sluice valves in the engine-room, or to such other purposes as it may be found necessary, or desirable, to apply the available water power.

The pumping engines are direct-acting, with two inverted cylinders arranged over the crank shaft, and each set of engines operates two bucket and plunger pumps, directly from the piston rod crossheads. Each pair of engines is capable of developing not less than 166 actual horse-power, when working with steam at 160lbs. pressure per square inch, and running at 58 revs. per minute; and the combined capacity of the two pairs of engines and two sets of pumps is that of supplying not less than 630 galls. of water per minute, at 750lbs. pressure per square inch.

The cylinders are two in number, the high-pressure cylinder being 17in. diam., and the low-pressure cylinder 36in. diam., both having a clear piston stroke of 18in. The cylinders and covers are steam-jacketed, the cylinder bodies being covered with asbestos composition, lagged with wood, and cased in with highly-planished steel sheets. The pistons are of the Rowan type.

The back columns are of cast iron, of the box form, and are suitably arranged to receive the guide bars and pumps, accurately machined and attached to the cylinders and to the bedplate by bolts and nuts. The front columns, four in number, form the receptacles for the pumps. The bedplate, which is of the box form, is of cast iron, ribbed and bracketed throughout. The flywheel is of cast iron, of disc form; it is 7ft. diam., and is 12in. in breadth on the face, being properly balanced to ensure steady running.

The hydraulic pumps are four in number, and are of the bucket-plunger type, each plunger being $5\frac{1}{4}$in. diam.; they have a separate gland packed with hydraulic packing. The bucket is $7\frac{1}{2}$in. diam. The bucket valves, head valves, and foot valves are of the multiple type, each set consisting of nine valves, of $1\frac{1}{4}$in. diam. These valves are cut from the solid, and all valves, seats, and guards are cast from a special mixture of hard bronze. The stems at the tops of the valves are prolonged, and work in guides forming part of the guards, each valve being provided with a spiral spring made from brass of high tenacity. The glands for the rams are of polished steel, each being secured by four turned steel studs of $1\frac{3}{4}$in. diam., and all gland nuts are provided with suitable locking arrangements. Each inlet to any of the suction valves is provided with a stop valve, and all necessary pipe connections between the pumps and accumulator are provided.

The hydraulic accumulator is of the suspended type. The ram is 18in. diam., and 20ft. stroke. It is provided with a special bayonet arrangement to prevent its being blown out of the cylinders. The body of the ram is $2\frac{1}{2}$in. thick. The top end of the ram is fitted with a cast-steel crosshead, which is arranged to receive eight steel suspending bolts, for attachment to the weight casing. The cylinder shell is $3\frac{3}{4}$in. thick. The weight casing, which is cylindrical, is 10ft. 6in. diam., and 18ft. in height. It is weighted with a mass of concrete, amounting to about 78 tons.

Among the accessories may be mentioned a cast-iron suction tank, 10ft. long, 6ft. wide, and 5ft. 6in. deep, which is capable of holding about 2,000 galls. of water. All parts which are subjected to accumulator pressure have been tested to a pressure of 2,500lbs. per square inch. The pressure pipes have diameters ranging between 6in. and 3in., and the return piping diameters ranging between 4in. and 7in. These pipes are of cast iron, composed of a special mixture for hydraulic work. The pressure pipes are fitted with momentum valves, where necessary.

Boilers, Feed Heater, and Steam Piping.—The steam installation comprises four Babcock & Wilcox water-tube boilers of the marine type, each having a heating surface of 3,590 sq. ft. and a grate area of 105 sq. ft. Each boiler is hand-fired and is composed of 31 sections of tubes, each section being 11 rows in height, the tubes being $3\frac{3}{16}$in. outside diameter by 10ft. 9in. long. The boilers are each provided with a Babcock and Wilcox integral superheater having a heating surface of 550 sq. ft. and being capable of increasing the temperature of the steam by 100° Fah. at the engines. The contractors for the pumping plant having stipulated that the boilers should be capable of evaporating altogether at the rate of 64,000lbs. of feed-water per hour, it was arranged that each boiler should be capable of evaporating 16,000lbs. of water per hour. The boilers and superheaters have been constructed for a working pressure of 170lbs. per square inch.

Two duplex direct-acting steam feed pumps (10in. by 6in. by 10in.) are provided. The pumps draw from the water storage tank, and discharge into the feed-heater and thence onward to the boilers. The feed-heater, which is of the Royle vertical cylindrical type, fitted with Row's indented tubes, is capable of heating the feed-water to about 200° Fah. at the boiler pressure of 170lbs. per square inch when working at full power.

The steam main runs at the back of the boilers, with which they are connected by means of four 5in. branch pipes. The piping is 10in., 7in., 5in., and 2in. diam. respectively, and is composed of weldless mild steel. The scantlings of the pipes and flanges are as follows:—

Bore of Pipe.	Thickness of Pipe.	Thickness of Flange including Facing Strip.	Radius of Bends.	
Inches.	Inch.	Inch.	Feet.	Inches.
10	$\frac{5}{16}$	$1\frac{1}{4}$	3	6
7	$\frac{1}{4}$	$1\frac{1}{8}$	2	0
5	$\frac{3}{16}$	1	1	6
2	$\frac{3}{16}$	$\frac{11}{16}$		8

Hydraulic Capstans.—There are in the dock equipments five capstans which are worked by hydraulic power, three of them being of 30 tons and two of 11 tons capacity each respectively, the water power by which they are actuated being supplied at a pressure of 750lbs. per square inch. The delivery or pressure pipes vary between 6in. and 3in. diam., and the return pipes to the accumulator-house vary between 4in. and 7in. diam. The three largest of these capstans are

the most powerful which have ever yet been employed as graving dock accessories at any port in the world, the next largest size in use in dockyards being those adopted by the Admiralty, which are only of 16 tons capacity each.

The capstans are all double-powered, the three largest being each capable of giving a hauling stress of 30 tons direct from the capstan barrel with a single rope at a speed of about 30ft. per minute, while their gearing is so arranged as to give a lower hauling stress of 7½ tons at a speed of about 120ft. per minute. The two smaller-power capstans are capable of exerting a hauling stress of 11 tons direct from the capstan barrel, at a speed of 30ft. per minute, and a speed of about 50ft. per minute when exerting the lower hauling stress of 7 tons. The capstan heads are fitted with pawls for use when it shall be found necessary to operate the capstans by hand.

Caisson Gate.—The gate at the entrance to the dock is of the travelling caisson type, comprised mainly of steel, and having, at its top, an automatic folding bridge, which, by a parallel-bar arrangement, is lowered as it enters the caisson recess, and raised when it clears the recess. When lowered the caisson can be travelled upon rollers into a caisson recess, which latter is roofed over, and is formed into a roadway for vehicular traffic. The caisson is rectangular in shape, one of its sides being longer than the other. The shorter side is intended to bear against the south granite meeting faces of the inner sill of the entrance. The longer side is intended to bear against the north meeting faces of the latter sill, and as well against the granite meeting faces of the outer sill of the entrance. So that when the caisson is in its normal or inner track the length of the dock on the floor is 850ft., and when it is placed against the meeting faces of the outer sill the length is 886ft. 7in. This interchangeability has been found to be of the utmost value in the docking of the s.s. "Olympic" and "Titanic."

The caisson is in length on one side 103ft. 4in., and on the other side 98ft. 4in. It is in clear width over the greenheart meeting faces 18ft. 4in., and in height from the bottom of the keelsons, which bear upon the rollers, to the roadway surface of the folding bridge 42ft. 4in., which latter is level with the coping of the side walls of the dock entrance. The caisson is divided into two compartments, the lower of the two being an air chamber, and the upper a water-ballast chamber; the latter is provided with valves, two on either side of the caisson, by the manipulation of which the tidal water may be admitted or excluded as may be desired and as may be found necessary. When the caisson is in place, in order to counteract its tendency to rise as the tidal rise increases, it may be necessary to open the valves on the seaward side, so that the tide may ebb and flow in the water-ballast chamber, or to close those valves to retain any constant desired quantity of water in the latter chamber for steadying purposes. A water-tight deck divides the above two compartments, and the valves referred to are placed at this deck level, bends being led from them on both sides of the caisson below the level of the dock and communicating with the tideway. These bends are fitted with proper rose heads in order to prevent floating matter from being carried into the chamber. The valves are controlled from a partial deck about 5ft. below the upper surface of the roadway bridge of the caisson. In order to gain admission to the lower or air chamber of the caisson, two vertical water-tight tubes or trunks, 30in. diam., are provided. At the bottom of the air chamber are stowed the portable ballast blocks. Below this portable ballast there is the permanent ballast, consisting of concrete, laid in situ in the ordinary way. The total weight of concrete ballast found necessary amounts to 986 tons, of which the weight of the permanent ballast is 288 tons, and that of the portable ballast 698 tons. With this quantity of ballast the caisson will float when the water-ballast chamber is empty, the draught being 30ft., and with a depth of water on the entrance sill of 35ft. 3in. The structural weight of the caisson is about 455 tons, which, together with all ballast, amounts to a total weight of 1,441 tons. The caisson, when in its normal track, rests, by its two longitudinal steel keelsons of 8in. by 4in. section, upon 52 cast-iron rollers placed in cast-iron roller boxes, which latter are built into the floor of the caisson track. The roller spindles are of mild steel lined with gun-metal.

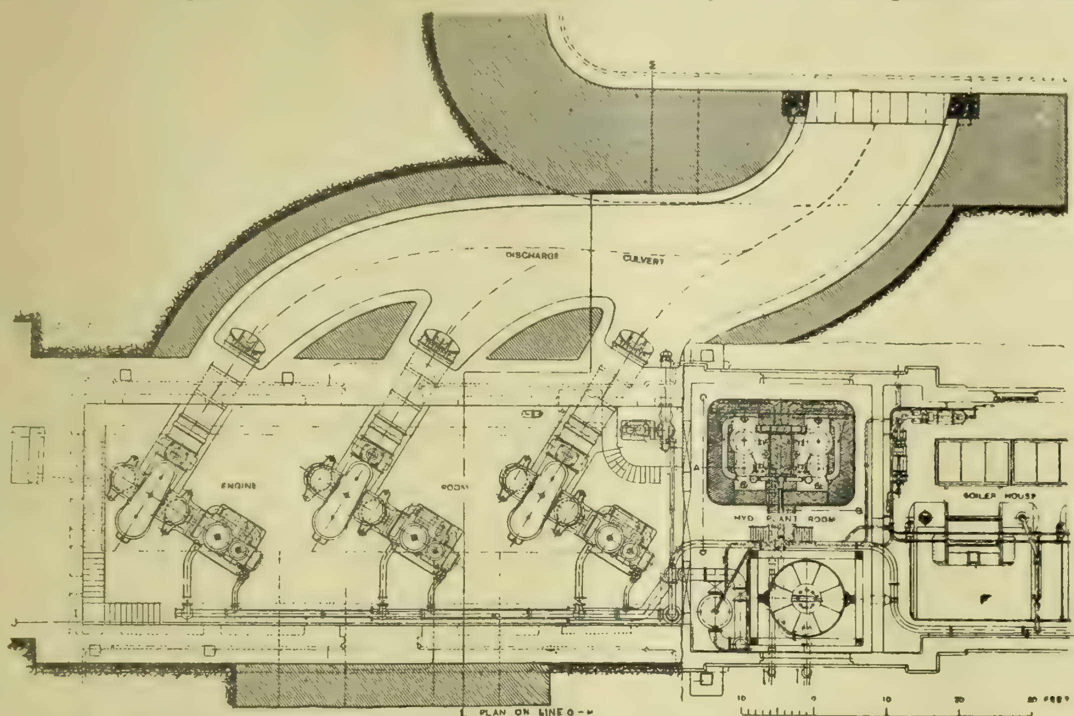


FIG. 2.—MACHINERY FOR EMPTYING THE DOCK. NEW ENGINE ROOM, HYDRAULIC PLANT ROOM, AND PART OF BOILER HOUSE.

When the lengthening of the dry dock space, beyond 850ft. on its floor, becomes necessary, the hauling yoke of the caisson is temporarily disconnected, the several valves of the water chamber are closed, and as the water rises and the displacement of the caisson becomes equal to its floating weight, the vessel will float and can be removed, as a ship or pontoon, to the outer meeting face of the dock entrance above the apron. The valves are then opened and the caisson is sunk in the outer track.

Four adjusting boxes, with screw and links of steel, are fitted to the ends of the caisson, two at either end. They are worked from the upper stringer by means of a key. These are for bearing the caisson up against the granite meeting faces. The two endless hauling chains, which are supported by 20 cast-iron rollers along each side of the caisson recess, are 1¼in. short link. The driving shafts are 8¾in. and 8in. diam. respectively, each having a boss for a chain pulley, and cast-iron couplings are turned and keyed on the shafts, and are fitted with turned bolts and nuts.

Caisson Hauling Plant. — The hydraulic plant which has been provided for the hauling of the caisson gate either into or out of the recess in the process of opening or closing the dock, is housed in an underground chamber on the eastward side of the dock entrance. It is capable of being actuated either by hydraulic power, or, in case of emergency, by manual power. The machinery is coupled up to a driving shaft in the caisson recess, which shaft is provided with two sprocket wheels engaging a pair of endless chains that are attached to the hauling yoke fitted on the end of the caisson; the chains are supported on a series of rollers placed along both sides of the caisson recess 5ft. and 6ft. 9in. respectively, below the surface of the quay. When this machinery is being worked by hydraulic power under the accumulator pressure before referred to, it is capable of exerting a hauling force of 24 tons

on the caisson at a speed of 14½ft. per minute, or 12 tons at a speed of 29ft. per minute.

The hydraulic engine is of the horizontal type mounted on a cast-iron bedplate, and has three cylinders fitted with rams, crossheads, and connecting rods acting directly on the crank shaft. The working valves are of the slide pattern, actuated by eccentrics on the crank shaft and fitted with reversing slides which actuate, through a shaft and levers, by a hydraulic cylinder. The spur gear is provided with two sets of gearing wheels to give the two powers above referred to, a clutch being fitted for putting either set of gear into or out of gear; the clutch is actuated by a portable hand lever from above the quay level. The hand gear consists of a head with sockets for hand spikes and bevel gearing driving on to the intermediate shaft. The motion of the hydraulic engine is controlled by a gun-metal valve operated by a portable hand lever from above the quay level; the reversing cylinder being operated by means of the same valve and lever.

Penstock Doors for Culverts.—There are nine penstock sluice doors on the various dock culverts, namely, four 9ft. by 9ft., one 7ft. 6in. by 6ft., and four 7ft. 6in. by 5ft., clear openings. These doors are operated by hydraulic power supplied at a pressure of 750lbs. per square inch, and are arranged that in case of a failure of the water pressure the sluices can be opened and closed by hand power. The doors are double faced, and are constructed of greenheart beams. For the 9ft. by 9ft. doors there are 10 beams, each 10ft. 8in. long by 13in. deep and 18in. wide. Each door has a massive cast-iron beam at the top, having eyes to receive the pin which connects the sluice rods to the door. The hydraulic cylinder for operating the door is of cast iron, 20¾in. inside diameter and 3⅜in. thick. The sluices are operated by a 1in. double-ported slide valve. The valves are operated by a hand lever made so as to be removable and working through a slot in the chamber covers.

The door, 7ft. 6in. by 6ft. in the clear, is constructed on the same lines as above; the greenheart beams being eight in number, 7ft. long, 12¾in. deep, by 14in. wide. The cylinder for operating same is 15⅛in. diam. and 2½in. metal.

The four 7ft. 6in. by 5ft. doors are also constructed as above, the greenheart beams being eight in number, 6ft. long, 12¾in. deep, and 13in. wide. The cylinders are 10in., 11½in., and 12¼in. diam. respectively, according to the head or depth under which the sluices require to work, the thickness of metal being 1⅝in., 1⅞in., and 2in. The operating slide valves are ¾in. diam.

The chamber covers for all the sluices are of cast iron chequered on the top, and placed in a check made in the granite masonry. Slots and eyes are founded in the plates through which to reach the working valves, so that the sluices can be operated without removing the plates. All those parts which are subjected to hydraulic pressure are designed for a working pressure of 750lbs. per square inch, and were tested to a pressure of 2,500lbs. per square inch.

POWER RATING OF MOTOR-CARS.

THE report of the Committee on the horse-power rating of motor-cars was issued on Monday last as a White Paper. The Committee state that motor-cycles have not been defined in an Act of Parliament, but are always taken to be mechanically propelled carriages having not more than three wheels and weighing unladen not more than 3 cwt. Under the Finance Act these vehicles are all taxed at a uniform rate of £1 irrespective of horse-power, and they do not come within the provisional regulations with which the Committee have to deal. Some motor-cycles, however, have engines whose power under any system of rating must be reckoned equal to that of the smaller classes of motor-cars. On the other hand, the Committee are informed that a class of very light vehicles is coming into existence which are designed on the lines of motor-cycles and have small engines, but have four wheels. These "cycle-cars" pay a two-guinea tax against £1 paid by a motor-cycle fitted with an engine of equal or greater power, and this solely because they have four wheels instead of two or three.

Though this subject is perhaps strictly outside their reference, the Committee have thought it well to draw attention to the facts, and to suggest that the present anomaly in the relative amount of the tax paid by certain motor-cycles and by certain motor-cars might be removed by an alteration in the system of classification adopted in the Finance Act, 1909-10. In the opinion of the Committee, it would be more rational to discontinue the separate treatment of motor-cycles, to classify them as motor-cars, and to rate them for horse-power as such. They suggest that if this be done the schedule of rates of duties should be amended by the addition of a class of cars not exceeding 5 h.p., and paying £1, so that it would read as follows:—

Motor-cars not exceeding 5 h.p., £1; exceeding 5 h.p. but not exceeding 6½ h.p., £2. 2s.; exceeding 6½ h.p. but not exceeding 12 h.p., £3. 3s., &c., the remainder being the same. This would have the effect of keeping the tax on the great majority of motor-cycles and of motor-cars at the present level, but would put on a fairer basis both the high-powered motor-cycles and the light low-powered "cycle-cars."

The Committee recommend that the provisional regulations now in force be replaced by the following amended regulations:—

(1) For the purposes of these regulations the horse-power of any motor-car deriving its motive power wholly from an internal-combustion engine worked by a cylinder or cylinders shall be taken to be: (a) In the case of a single-cylinder engine the horse-power attributable to the cylinder of the engine; (b) in the case of an engine having two or more cylinders the sum of the horse-powers attributable to the separate cylinders.

(2) The horse-power attributable to any cylinder of an internal-combustion engine shall be deemed to be equal to the square of the internal diameter of such cylinder measured in inches, divided by a numeral: (a) In the case of a single-acting cylinder having a single piston the numeral used as divisor shall be 2·5; (b) in the case of a single-acting cylinder having two pistons the numeral used as divisor shall be 1·6.

(3) The horse-power of any motor-car deriving its power wholly from a steam engine shall be taken to be proportional to the effective heating surface of the boiler supplying steam to such engine at the rate of 1 h.p. for every 3 sq. ft. in such effective heating surface, and the effective heating surface shall be taken to be: (a) In the case of a boiler having horizontal or approximately horizontal tubes, the whole of that surface of the tubes which is exposed to the flame or hot gases; (b) in the case of a boiler having vertical or approximately vertical tubes, half of that surface of the tubes which is exposed to the flame or hot gases.

(4) Any motor-car deriving its motive power from an electric motor or motors shall be deemed to be of a horse-power exceeding 6½ but not exceeding 12.

(5) In measuring cylinders and boilers and in calculating horse-power, fractions of inches and feet and fractions of a unit of horse-power are to be taken into account.

(6) Where it appears that in consequence of the exceptional design or construction of the engine of any motor-car the horse-power as calculated under the preceding rules is substantially less than the average power which the engine would develop in continuous use on the road if there were no restrictions on speed other than those imposed by the car itself, then such average power shall be taken as the power of the car.

A Fatal Emery Wheel Burst.—A serious accident occurred on Monday last at Messrs. J. Butler & Co.'s Stanningley Iron-works, resulting in a plater being instantly killed. The plater was grinding a "drift" at an emery wheel when the latter burst, a large portion of it striking him full in the face and smashing his skull.

Explosion of Acetylene Gas Tanks.—According to the "Engineering News," an explosion of three gas tanks occurred at the plant of the A. O. Smith Company, at Milwaukee, Wis., on August 26th, killing one employé and injuring six others. The tanks were used for the storage of acetylene gas for welding purposes, and one explanation offered for the accident is that the gas was ignited by back firing from the welding machine. The pressure on the tanks at the time of the explosion was 40lbs. per square inch.

POWER IN TEXTILE MILLS.*

SOME time ago, at the suggestion of the local committee of the Institution of Electrical Engineers, a joint committee, consisting of members of that body and of the Textile Institute, was formed to investigate and report on the best methods of driving textile factories. Shortly after its formation it was for many reasons considered desirable that such a committee, which had to report on what might be termed rival systems, should be elected independently of the great engineering institutions, and a decision was arrived at to confine the membership of the committee to members of the Textile Institute itself. The work of this new committee when fully formed will be to report periodically to the Council on the various methods of mill driving and on any improvements or developments that may be introduced either in this country or elsewhere, and it will be on this account a permanent committee of the Institute.

The authors, when they consented to read these papers, did so on the understanding that they were to form merely a general introduction to the exhaustive and detailed treatment which this subject is subsequently to receive at the hands of this special committee. It is obviously not possible in a single paper to treat in detail of the various matters connected with the drives advocated, though these are, of course, of distinct interest to the textile manufacturer, nor indeed were it possible would it be desirous to do so, since these details are afterwards to be made the subject of systematic investigation. Prior to the writing of the papers the authors held several meetings, chiefly with a view to the adoption of a standard basis of estimating, so that any figures given in one paper might be readily comparable with corresponding figures in any other. They believe that the majority would prefer simple practical statements, and have agreed, so far as is possible, to adhere to these.

In endeavouring to arrive at a basis for expression of results, an important difficulty is at once obvious, viz., the adoption of a common power unit. The majority of manufacturers, using as they do reciprocating steam engines, think and speak in indicated horse-power. The indicator is applicable to the gas engine and the oil engine, as well as to the steam engine, and records with reasonable accuracy the work done on the piston. Unfortunately for comparative purposes, the net or useful power commonly called brake or shaft horse-power is not proportional to the indicated horse-power for any two engines. Again, with the indicator it is not practicable to ascertain the horse-power of a steam turbine. Still, again, electrical power plays an important part in factory driving, and is destined to play a much larger part in the future. While electricity is purchased by the Board of Trade unit and electrical engineers think and talk in kilowatts, here, however, the difficulty is not so great, as the kilowatt and the brake or shaft horse-power bear a constant ratio to one another, viz., 1,000 to 746, and so are readily convertible. The authors have decided to adopt the brake horse-power as their standard. In good steam-engine practice the brake horse-power is to the indicated horse-power as 9 : 10, in good gas-engine practice as 8·5 : 10, and in Diesel oil-engine practice as 8 : 10. These ratios are arbitrarily adopted for the papers, but purchasers of prime movers or motors of any type can always obtain guarantees of mechanical efficiency from the makers, and, should these not correspond with the ratios given above, the conversion and adjustment is a simple one.

The following basis for running costs and charges have likewise been adopted for each paper:—

Running hours per annum: For the spinning mill or weaving shed, 2,750.

Interest and depreciation on engines, turbines, and electrical machinery, 10 per cent.

Interest and depreciation on boilers, gas plant, tank work, and the like, 10 per cent.

Interest and depreciation on buildings and foundations, 8 per cent.

Labour: Skilled engineers, £120 per annum.
Mechanical and electricians, £100 per annum.
Labourers, firemen, &c., £65 per annum.

Fuel: Steam or bituminous producer coal, 11s. per ton.
Anthracite, 32s. per ton.
Coke, 13s. per ton.
Diesel oil, 50s. per ton.

It is the authors' sincere wish that the papers will do something towards assisting textile manufacturers in deciding upon the most suitable procedure in each instance when new works are to be built or old ones extended or altered.

STEAM POWER IN TEXTILE MILLS.

BY GEORGE B. STORIE.

STEAM ENGINES.

Although steam-power installations have reached a high state of efficiency, it would hardly be correct to say that the highest point of perfection had been arrived at in the utilisation of steam in the production of motive power. Since the resuscitation of the drop valve and its application to the modern reciprocating engine and the introduction of the steam turbine, steam consumptions have been materially reduced, and, leaving the enhanced price of coal out of the question, the cost of steam power to-day given off at the flywheel or electric generator is considerably less than it was 20 years ago, and everything points to still further reduction.

There is little resemblance between the old beam engine of 50 years ago and the present type of mill engine. Steam pressures and piston speeds have increased enormously, and where at one time working steam pressures of 30lbs. and piston speeds of 150ft. per minute were about the standard, today pressures up to 200lbs. are common with piston speeds of 800ft. per minute. To go further, and compare the beam engine crank shaft running at about 25 revs. per minute with the main shaft of a steam turbine making 10,000 revs. in the same period of time with equal safety, the progress made is still more remarkable, and points to the great achievements of mechanical engineering during the last half-century.

No country in the world produces finer engines than those found in the textile factories of Great Britain. They are scientifically designed, the minutest details have attention, and excellent workmanship and materials are used in their construction, with the result that the machine can be relied upon to perform its work with safety for a long period of years.

In the selection of a prime mover for driving a textile mill the chief determining factors are reliability, uniformity of speed, and economy. It will therefore be the endeavour of the author to show that by utilising the heat energy in steam generated in a boiler, and converting it into mechanical energy by means of a reciprocating engine or steam turbine, or by a combination of both, these three important requirements can be obtained irrespective of the manner in which the power is conveyed to the machines in the factory. Reliability has been intentionally mentioned first, because without it it is impossible to work a plant with economy, and its absence always more or less seriously interferes with production, both in the spinning mill and the weaving shed.

The single-cylinder engine is seldom used except for very small powers, and mill engines are now always arranged to work either on the triple-expansion or compound systems. A large number of triple-expansion engines have been installed in textile mills, but the tendency for the time seems to be to return to the compound type, and this in a great measure is due to the introduction of superheated steam, which has enabled the compound engine to compete on equal terms with the triple expansion.

For many years engines fitted with Corliss valves have been recognised as the standard type for mill driving. This class of valve, however, is not suitable for use with highly superheated steam, as when exposed to high temperatures the valve binds in its chamber, and a large quantity of lubricant has to be used to keep the valve free. Again, to overcome the pressure on the valves of large Corliss cylinders powerful gear is required, which, together with the valves, is responsible for a considerable amount of friction. There is also the

* Abstract of papers presented at the Hawick meeting of the Textile Institute, September, 1912.

further disadvantage that after a few years' service the working surfaces wear sufficiently to allow of steam leaking past the valve into the cylinder. A steam distribution valve was therefore called for that would work satisfactorily when exposed to high temperatures and remain steam-tight under all working conditions, and at the same time offer less resistance to the moving parts.

Continental engine builders, appreciating the value of superheated steam when it was introduced, at once set about constructing engines suitable for working with steam at high temperatures, employing for distributing the steam the drop valve, which had been extensively used on the Continent for a number of years on engines working with saturated steam. The cylinders of these engines have been designed to withstand very high temperatures, and fine working clearances are used, which necessitates very careful adjustment of the parts. The manufacture of some of those engines has been taken up by several engineering firms in this country, and already a considerable number have been installed for driving mills.

Some remarkable results as regards steam consumption have been obtained from drop-valve engines, but so far there has been no performance approaching that of the engine belonging to the Durham Street Weaving Company, Belfast, which was shown by a carefully-conducted test to be using only 8·7lbs. of steam per indicated horse-power per hour. The temperature of the steam at the engine stop valve was 700° Fah., and to obtain this an independently fired superheater was used. This engine has been at work for nine years, and the author understands that, with the exception of minor repairs to the valves, nothing has been done to the engine since it was set to work.

A side-by-side drop-valve engine by Douglas & Grant, working at York Road Mills, Belfast, was tested about a year ago, when the engine was working with saturated steam, and from the following particulars it will be seen that the result of the test was extremely satisfactory.

High-pressure cylinder, front—159 i.h.p.
High-pressure cylinder, back—180 i.h.p.
Low-pressure cylinder, front—123 i.h.p.
Low-pressure cylinder, back—132 i.h.p.
Total indicated horse-power per hour—595.
Gross steam consumption per indicated horse-power hour, making no allowance for water drained from separator or jacket—11·9lbs.
Water collected from high-pressure jackets—144lbs.
Water collected from low-pressure jackets—72lbs.
Net steam consumption per indicated horse-power hour if separator and jacket water deducted—11·8lbs.

What the life of those engines working with highly superheated steam will be, time alone can tell, but if they are to run with the highest degree of working safety, nothing but the finest workmanship and material will serve.

STEAM TURBINES.

The steam turbine is likely to play a great part in the driving of textile mills in the future. It has already made rapid progress, and a large number of turbines have been installed for textile mill driving on the Continent. It is, however, only within the last few years that its merits have been recognised in this country, but the number installed continues to increase, and it is interesting to note that the three largest textile concerns in Britain have now adopted turbines for driving their mills.

The turbine has been sufficiently long in service to allow of a judgment being formed as to its capabilities, and as regards reliability, about which there was some doubt when the earlier machines were installed, there is now no question, and the turbine ranks in service with the reciprocating engine. Evidence as to the confidence placed in its behaviour can be obtained at almost any large power station in this country, where comparatively few turbines can be seen doing the work once performed by a large number of reciprocating engines now standing idle.

In the early days, like most other new machines, the turbine had to encounter difficulties, and breakdowns, due almost entirely to defective blading, were frequent. These defects, however, have disappeared, and the systems of blading now used by the leading turbine builders are such that stripping of blades has almost become a thing of the past. The turbine is a perfectly simple machine; there are no rubbing surfaces inside the cylinder, nor are there any complicated valve gears. The only bearings are those which support the rotor and its shaft, and as they are continuously lubricated with oil under pressure there is practically no wear.

If the best results are to be obtained, both as regards production and quality of material, the prime mover from which the power is obtained for driving the machines in a textile mill or weaving factory must run at a uniform speed. In this respect the turbine offers very great advantages, as, owing to its absolutely uniform turning movement, combined with great storage of kinetic energy in the revolving parts, the speed regulation can be accomplished in a more efficient manner than is possible with reciprocating engines. As an illustration of the steady running of the turbine, it is only necessary to see the power station, where turbo-alternators run perfectly in parallel with alternators driven by reciprocating engines, giving a more constant voltage than can be obtained when the reciprocating engines are working alone.

To secure economical working it is of the utmost importance that the turbine should be worked with a good vacuum, as the expansion of the steam in the turbine can be carried right down to the pressure in the condenser, a function which is practically impossible in the case of a reciprocating engine on account of the excessive size of the low-pressure cylinder, and also of the ports, passages, and valves which would be required. The benefit derived therefore from a good vacuum is much more in a turbine than in a reciprocating engine.

The effect of difference of boiler pressure is relatively smaller in turbines than in reciprocating engines, and it is doubtful if the gain in economy due to working with pressures higher than from 160lbs. to 200lbs. is sufficient to justify the increase. Superheating has a marked influence on the steam consumption, and nearly all turbines are constructed to allow of working satisfactorily with steam at temperatures up to 600° Fah.

No oil of any kind is used in the interior of the turbine, nor in the glands through which its shaft passes, thus eliminating a heavy expense. In many cases, however, the absence of oil in the exhaust steam results in a much greater saving than the cost of the oil itself. For instance, it is well known that grease is a bad conductor of heat and that its presence in boilers affects their efficiency and durability. The absence therefore of oil in the condensed steam when used for boiler feed would result in better efficiency, and the life of the boiler would be increased as well.

In some branches of the textile industry the nature of the work is such that the smallest quantity of oil in the steam would render it unfit for use, and live steam is taken direct from the boilers. With clean exhaust steam from a back-pressure turbine this expense could be avoided and considerable economy effected. As the bearings and governor are the only parts that are lubricated, the cost for oil is extremely low, and may be taken at about 1 per cent. of the cost of the fuel used, whereas for a reciprocating engine it would be in the region of 8 per cent.

Owing to improvements in design the steam consumption of the turbine has been materially reduced during the last five or six years, and with powers of from 200 kw. to 1,500 kw. the performance of the turbine is equal to that of the best type of reciprocating engine. With larger units the turbine gives the more favourable results.

The advantages of a steam turbine are now fully recognised; some have already been referred to in detail, but briefly they may be stated as follows: small number of moving parts, few repairs, no internal lubrication, uniform speed, small space required, and low first cost. These are important factors, as the working safety of a machine is, as a rule, greater the less its running depends upon the man in charge, and it also can be superintended more effectively the fewer parts it possesses, the simpler these parts are in their construction, and the smaller the space they occupy. When therefore we consider the ease with which a turbine can be started and the small attendance required during its working, it must be recognised as the simplest heat power engine of the present time.

In October of last year exhaustive tests of a 1,000 kw. turbo-generator were carried out by a number of continental engineers, and remarkable results were obtained. When developing 972 kw., with steam at a pressure of 162lbs., superheated to a temperature of 667° Fah., and with an absolute pressure of 1·43lbs. in the exhaust pipe, 11·55lbs. of steam was consumed by the turbine per kilowatt hour, and 8lbs. of steam per brake horse-power hour. This is probably the lowest steam consumption that has been obtained with a steam generator.

Since the turbine is capable of utilising the highest vacuum obtainable, and so using the large number of thermal units available from the expansion of steam to a very low pressure, there is a wide field open to the low-pressure turbine, and its advent provides means for recovering quantities of energy that are blown to atmosphere and discharged into drains in the form of heat.

The fact therefore that it is possible to further carry on the expansion of steam after it has been used in the cylinder of an engine by employing an exhaust turbine makes it possible to increase the output and economy of existing engines when additional power is required, and in the majority of cases this can be accomplished at considerably less cost than if a complete new reciprocating engine had to be installed.

When an exhaust turbo-generator is used in series with an engine driving a mill mechanically it is necessary to provide a balancing generator, which is driven from the engine, so that the load can be divided between the reciprocator and turbine, under any conditions of working. Otherwise exhaust steam would be discharged to the atmosphere when the load on the turbine was not sufficient to utilise the whole of the steam from the engine.

In works where the dyeing and finishing of textile materials is carried on and where comparatively large quantities of low-pressure steam are required for boiling and drying, turbine driving offers special advantages. In generating steam in dyeworks, a common practice is to instal batteries of high and low-pressure boilers, the former supplying steam for power and the latter for manufacturing purposes. In some works high-pressure boilers only have been installed, and the steam reduced to the necessary low pressure by means of reducing valves. If in this arrangement the reducing valve is replaced by a back-pressure turbine in which the steam required for boiling and drying is allowed to expand to the desired low pressure, great economy can be effected, and, in addition to the plant being highly efficient, power for driving the works is available at a cost considerably less than it could be obtained from any other source.

Excepting paper works and sugar refineries, there is probably no factory where steam is used that offers greater opportunities to the engineer of effecting economy than a dyeing establishment.

It is necessary to include in the cost of working a power installation the whole of the expenditure (direct and indirect) which is incurred in the production of the actual work done by the engine, and in Tables II., IV., and VI. this sum is represented in relation to the working year and to the unit of work done per horse-power and per kilowatt hour.

In referring to Tables I., III., and V., the marked difference in price between the reciprocating engine and the turbine will be noticeable, especially in the case of the electric drive. Again, on the question of buildings, owing to the small size of the turbine the room required to house it is considerably less than that required for the reciprocating engine, and this, with the small foundation called for by the turbine, again shows a considerable reduction in first cost in its favour.

As regards running costs, the fuel consumption is the same for both machines, but owing to the few working parts and the small attention required by the turbine, the costs for labour, repairs, oil, and stores are exceedingly low, and it is doubtful if any of the other prime movers can surpass the turbine, at anyrate so far as these costs are concerned.

It is not uncommon practice to judge the economy of an installation by the fuel or steam consumption. This, however, is not alone sufficient to allow of a true estimate being formed of its overall economy, as many instances could be given where the running costs of prime movers, working with low fuel consumptions, are exceptionally high, so high, in fact, that any gain due to the reduced fuel consumption is more than counterbalanced by extra expenditure in repairs, attendance, and stores. It is therefore imperative when a new plant is in contemplation that the steam user should take means of ascertaining how many other items have to be added to the cost of the fuel, in order to know how much the production of his power will cost, before he decides upon the prime mover that is to drive his mill, as only after all the expenses are taken into account will it be found what share the cost of the fuel has in the total result.

TABLE I.—*Electrical Drive* (A).

Turbo alternator, 750 kw., 500 volts, 3-phase, 50 periods, 3,000 revs. Boiler pressure 160lbs. Steam superheated to 550° Fah. Temperature of cooling water 80° Fah.

Item	£
Turbo-alternator	£2,150
Surface condensing plant, feed pump, and pipes, &c.	850
Three Lancashire boilers, 30ft. long by 8ft. 6in. diam.	1,350
Economisers	259
Three superheaters	255
Mechanical stokers	420
Steam and feed pipes	430
Travelling crane	90
Water cooler	380
Boiler-house and boiler and economiser foundations	1,500
Engine-house and engine foundations	600
Capital outlay	£8,581

TABLE II.—*Electrical Drive* (A).

Turbo-alternator 750 kw. (1,080 i.h.p.) at 2·3lbs. coal per kilowatt-hour, including banking of fires.

	Cost per annum. £	s.	d.	Cost in pence per I.H.P. per hour.
Coal, 2,117¾ tons, at 11s.	1,175	5	0	0·0941
Power for condenser and cooler	45	0	0	0·0036
Engine-house labour	120	0	0	0·0096
Boiler-house labour	65	0	0	0·0052
Boiler cleaning, &c.	12	0	0	0·0009
Boiler repairs	20	0	0	0·0017
Oil and stores	50	0	0	0·0040
Turbine upkeep and repairs	50	0	0	0·0040
Interest and depreciation on £8,584, at 10 per cent.	858	8	0	0·0687
	£2,395	13	0	0·1918

At 1,080 i.h.p. cost per i.h.p. per annum...£2. 4s. 4d.
At 750 kw. cost per kw. year ....£3. 8s. 9½d.
,, cost per kw. hour .... 0·3d.

TABLE III.—*Electrical Drive* (B).

Horizontal cross-compound condensing engine arranged for driving alternator, 750 kw., 500 volts, 3-phase, 50 periods, 86 revs. Boiler pressure 160lbs. Steam superheated to 550° Fah.

Item	£
Engine and alternator	£4,900
Three Lancashire boilers, 30ft. long by 8ft. 6in. diam.	1,350
Economisers	259
Three superheaters	255
Mechanical stokers	420
Steam and feed pipes	500
Travelling crane	150
Boiler-house and boiler and economiser foundations	1,500
Engine-house and engine foundations	1,350
Capital outlay	£10,684

TABLE IV.—*Electrical Drive* (B).

Horizontal cross-compound condensing engine, 750 kw., at 2·3lbs. coal per kw.-hour, including banking of fires.

	Cost per annum. £	s.	d	Cost in pence per I.H.P. per hour.
Coal, 2,117¾ tons, at 11s.	1,175	5	0	0·0941
Engine-house labour	185	0	0	0·0148
Boiler-house labour	65	0	0	0·0052
Boiler cleaning, &c.	12	0	0	0·0009
Boiler repairs	20	0	0	0·0017
Oil and stores	100	0	0	0·0080
Engine upkeep and repairs	110	0	0	0·0088
Interest and depreciation on £10,684 at 10 per cent.	1,068	8	0	0·0855
	£2,735	13	0	0·2190

At 1,080 i.h.p. cost per i.h.p. per annum..£2. 10s. 8d.
At 750 kw. cost per kw. year ....£3. 12s. 11½d.
,, cost per kw. hour .... 0·34d

TABLE V.—*Mechanical Drive* (c).

Horizontal cross compound condensing engine, arranged for rope drive. 1,080 i.h.p. Boiler pressure 160lbs. Steam superheated to 550° Fah.

Engine with condensing plant	£3,700
Three Lancashire boilers, 30ft. long by 8ft. 6in. diam.	1,350
Economisers	259
Three superheaters	255
Mechanical stokers	420
Steam and feed pipes	500
Travelling crane	150
Boiler-house and boiler and economiser foundations	1,500
Engine-house and engine foundations	1,300
Capital outlay	£9,434

TABLE VI.—*Mechanical Drive* (c).

Horizontal cross compound condensing engine. 1,080 i.h.p., at 1·6lbs. coal per i.h.p. per hour, including banking of fires.

	Cost per annum. £ s. d.	Cost in pence per I.H.P. per hour.
Coal, 2,117¾ tons, at 11s.	1,175 5 0	0·0941
Engine-house labour	185 0 0	0·0148
Boiler house labour	65 0 0	0·0052
Boiler cleaning, &c.	12 0 0	0·0009
Boiler repairs	20 0 0	0·0017
Oil and stores	95 0 0	0·0076
Engine upkeep and repairs	90 0 0	0·0070
Interest and depreciation on £9,434 at 10 per cent.	943 8 0	0·0755
	£2,585 13 0	0·2068

At 1,080 i.h.p. cost per i.h.p. per annum..£2. 7s. 10½d.

GAS POWER.

BY T. ROLAND WOLLASTON.

So far as the subject of mill driving is concerned, I prefer to regard a "Textile Institute" audience as composed of practical men, desiring practical results rather than notes on record breaking, and I deprecate the use of "testplate figures" on such an occasion. My duty is to point out its advantages as I know them, and to endeavour to clear away prejudices which certainly exist in some quarters, but I am as sure as anyone here that the steam engine, steam turbine, and Diesel engine must in many cases show advantages. We must all recognise that the fuel bill is far from being the only or even the most important item in mill driving economy.

The criticisms generally advanced to oppose the installation of gas engines in textile mills are set forth below. To each one is appended a short reply:—

(1) "They are sometimes stated to be uncertain in starting."

This criticism unquestionably arises out of early experience with engines fitted with so-called self-starters, and generally when used in conjunction with suction gas plants. The self-starter has given way in plants of any size and class to the independent compressed air starting plant, which renders the gas engine as easy or easier to start than any steam engine. Reference will be made to suction gas plants and their bearing upon this point hereafter. Ignition troubles, perhaps formerly the most serious, are now almost universally and satisfactorily overcome by duplicating the ignition gear.

(2) "There is said to be difficulty in maintaining a steady quality of gas both as regards composition and cleanliness."

This criticism, again, is largely founded upon experience with suction plants. Good plants of the positive type (the word positive is used to differentiate them from those depending wholly upon engine suction) present no difficulties, if worked with reasonable intelligence, in maintaining the composition of the gas constant. Clean gas is admittedly essential. It is quite easy to obtain if the plant be properly designed and controlled, and engines turning 500 h.p. to 3,000 h.p. are running to-day without having had cylinder or valve cover removed for cleaning for six months. I venture to refer you to the paper read before the Manchester Association of Engineers by my able colleague, Mr. Weil, on this point.*

(3) "Gas power plants are said to be more costly in the first instance than steam power plants."

Comparing the bare cost of gas engines and gas plants with the cost of steam engines and steam boilers, this may be correct. There are, however, so many adjuncts to the steam set; for example, the chimney or forced draught plant, sometimes the automatic stoker, the boiler setting, special pipes and fittings for high pressure and high superheat, feed pumps, lagging, and so on, which almost invariably bring the price up to, or near, that of the gas set. Mr. A. E. L. Chorlton, for his paper† recently read before the Manchester Association of Engineers, went to great pains to obtain check estimates, and his conclusions, substantially confirmed by my own experience, were to the effect that for plant as required for a modern textile mill there is little difference in first cost between gas and steam when all apparatus is taken into account. It must be remembered that we are considering high-class steam plant, involving high-pressure steam, superheat, and condensing. Recent improvements, moreover, in gas engine and plant design combined with ever-increasing output of the leading makers are tending to lower prices.

(4) "There is said to be liability of breakdown due to high internal temperatures and cylinder cracks."

That there have been several such failures is admitted. That the number of these is a steadily decreasing quantity must be also admitted. The problem of designing cast-iron cylinders to stand these temperature conditions has been among the most difficult which makers of large gas engines have had to face, and has called forth much ingenuity. The problem appears still more difficult of solution in Diesel engine design, while it is by no means unknown in superheat steam engine and turbine work. Modern designs and care in the foundry render the percentage of such accidents lower year by year.

(5) "Regularity of turning with gas engines is sometimes said to be insufficiently good for spinning mills."

This is another statement based wholly upon what may now be regarded as the ancient history of single and double-cylinder single-acting 4-cycle horizontal engines. During 30 years' experience with cotton mill engines, the best turning I have ever seen was by a gas engine.

(6) "Gas power plants are said to require more room."

For small powers this is not true. Of course, more space is required than for Diesel or other oil engines, but less than for steam engines with their boilers and adjuncts. For large powers with pressure bituminous gas plant, a somewhat larger area may be sometimes required. The gas plant, however, is composed of parts which may be coupled together in so many ways that it is frequently possible to arrange it on space impossible of utilisation for boilers of any kind, and it requires practically no housing and the simplest and cheapest of foundations. An important point is that distance apart of gas plant and engine is of no consequence. There is no condensation loss to consider, and gas mains are cheap. With so many reliable designs now available the engine-house dimensions need not exceed those required for steam or Diesel engines.

(7) **General Reliability.** — One can do no better than quote the published report of the performance of the Westinghouse engine and Mond gas plant at Hollins Mill, Marple, which is, I believe, word for word as supplied by Mr. Hodgkinson, the chairman, to whom, incidentally, all manufacturers of gas power plant and all textile economists are indebted for pioneer work in this important subject. His plant is upwards of six years old, and much important work has since been done in the direction of improving and cheapening gas plant and engines. I could quote plenty of examples as good or better, but choose this one, as the figures have been recently published and are common property, and I respectfully submit that what has been done in this case can now be excelled in any spinning mill or weaving shed of like size. Mr. Hodgkinson was not encouraged by his advisers to adopt by-product recovery on his comparatively low load and load factor, but, persisting, he has clearly demonstrated that it pays, and pays handsomely.

There are given in Appendix No. 1 the actual figures of running cost for the year 1911, as supplied by Mr. Hodgkinson, and in Appendix No. 2 figures adjusting these in accordance with the coal cost agreed upon in our introduction, together with what may be considered a safer basis for sale of ammonium sulphate, and taking into account of capital charges.

Reference has been made above to gas plants known as the

* Proceedings Manchester Association of Engineers, 1911-12, page 489.

† Proceedings Manchester Association of Engineers, 1910-11, page 1.

"suction" type. We have to recognise that the suction gas plant has been largely instrumental in bringing gas power to its present position of popularity, due to its cheapness, compactness, and simplicity. With eyes fully open to the criticism likely to fall upon me, let me confess that I do not like them, and I believe them to be responsible for at least one-half of the gas power installations pronounced unsatisfactory in textile mills.

I do not criticise the suction principle *per se*, but I would prefer to supplement the engine suction by fan suction in the first place, thus keeping the rate of blast through the fuel bed steady, if not constant. Such procedure has two further recommendations: the fan assists in cleaning the gas, and the added "pressure" permits the interposition of more adequate gas cleaning and drying plant. Then I would generate the steam in a closed vessel or coil, which might still operate through the agency of the hot gas issuing from the producer, but which would discharge under slight pressure to the blast inlet, and under valve control, automatic or otherwise.

Let us now turn to the features in which gas power appears to excel every other power in regard to textile mill driving.

(1) The fuel cost per brake horse-power for the gas engine as compared with that for a high-class steam engine is about in the ratio 5 : 9.

Comparing the gas engine fuel cost with that of the Diesel engine, rating the former at $1\frac{1}{4}$lbs. of coal and the latter at $\frac{1}{2}$lb. of oil per brake horse-power, prices respectively 11s. and 50s. per ton, we get :—

Gas Engine.		Diesel Engine.
$1{\cdot}25 \times 11$	:	$\times {\cdot}5 \times 50$
Say 14	:	25

Steam is always required for one purpose or another in textile mills, however driven. There may be obtained at least 2lbs. of steam per horse-power driven from boilers coupled to the exhaust pipe of the gas engines and receiving their heat from the waste products of combustion. That is to say, if in the steam-driven mill 20 per cent. of steam is required for heating, additional to the power steam, in the gas-driven mill about 11 per cent. of this or more than half would be provided without extra coal and substantially without attention.

Much of the balance of the heating steam can be raised by burning the tar produced under the boiler. Twenty-five tons of coal produce one ton of tar as an average, and a ton of tar will raise about the same amount of steam as a ton of coal. I am not aware of the exhaust from Diesel engines having been used to raise steam, though this may be practicable.

(2) The stand-by losses in banking up over week-ends and at nights are in the gas plant about one-quarter those of the average boiler-house. The Diesel engine, of course, excels here.

(3) Incompetency or carelessness on the part of the boiler-house staff, even when boilers are fitted with mechanical stokers, frequently lead to considerable loss in steam plant. Very few steam plants work normally within 10 per cent. of their supposed standard of economy. Like carelessness cannot well affect the gas plant in the same way. The stoking is a purely mechanical operation, performed as well by a novice as by an experienced man. The engineer in charge need only give very occasional supervision.

(4) The rate of gas production is in well-designed producer plants regulated automatically, and the efficiency falls away very little on low loads. When working under loads varying from 15 per cent. to 100 per cent. practically no extra care is required.

(5) The efficiency of the gas engine on low loads is considerably higher than that of the steam engine, and much higher than that of the steam turbine.

(6) There are with the gas plant no high pressures, no losses equivalent to pipe condensation, and no non-conducting coverings to provide and maintain.

(7) Quality of water supply is of no importance (except as regards the small amount for steam raising). If a water cooling tower be adopted the total amount of make-up water required is almost negligible, and no foul or greasy effluent need be turned away to pollute streams or drains.

(8) The maintenance charges upon a well-managed gas plant are considerably lower than upon the equivalent steam plant. Maintenance charges upon gas engines seem to be very variable from records available, but they average little, if any, more than those of the steam engines.

(9) I now arrive at a point which seems to me of the utmost importance in considering gas power for textile mills other than spinning and weaving, for example, bleaching, dyeing, and print works. Taking an informal census among friends engaged in these trades, I gather that of the total steam raised as a rule only about one-third goes to drive engines, the balance being used for heating and boiling. There is surely no occasion to point out the enormous losses thus entailed in condensation during work and after stoppage. We may take gas practically any distance to its work without measurable loss; we can apply it to dry, heat, or boil with far greater ease and facility for control than is possible with steam. We can maintain liquors at the boil or at any other temperature required without dilution due to condensation, and the apparatus necessary for all these processes is generally of a simpler and cheaper nature than for steam heating. Steam losses due to pipe and pan condensation are everywhere recognised, but their correct estimation in, for example, a large bleach works is a most difficult matter, and so far as I am aware no reliable data upon the subject has been published. Whatever it may be, and probably most here have views upon the subject, I submit it can be eliminated by substituting gas heating. That is to say, assuming that at the gas plant scrubber we get 75 per cent. of the fuel heat units as cool clean gas, and that at the boiler junction valve we get 70 per cent. of the fuel heat units in the form of steam, at the destination, be it a keir, calender, or drying machine, whatever distance away it may be, we get substantially the same value in gas; we get 10, 15, or 20 per cent. less value in steam dependent upon the pipe line and quality and condition of its covering.

(10) Finally, the advantage which is peculiar to gas power alone, namely, by-product recovery. I will not do more than refer you again to the Hollins Mill figures given in Appendix I. to advocate ammonia recovery plants for small private installations. The short working day of cotton mills is not favourable to attainment of the best results, and there is something in the argument that spinners and weavers do not wish to start as chemical manufacturers. Certainly on powers lower than 700 h.p. and the 10-hour working day the addition of ammonia recovery plant can hardly be at present recommended.

APPENDIX 1.

Extract from "Gas and Oil Power," June 6th, 1912.

HOLLINS MILL, MARPLE.

The cost sheet for 1911 comes out as follows:—

	£	s.	d.
Coal: 1,100 tons at 10s. 3d. per ton	563	15	0
Oil for gas engine	110	2	10
Oil for gas plant auxiliaries	2	15	2
Scrubber materials	1	0	0
Packing for steam engines	0	19	6
Acid for recovery plant	55	0	0
Repairs, renewals, &c., to engine and plant ...	5	4	6
Wages	300	0	0
	£1,038	17	0

Of these items, the repair bill is extraordinarily favourable. The credit side is as follows:—

	£	s.	d.
Tar burned: 75 tons at 12s. 3d. per ton	45	18	9
Sulphate recovered: $32\frac{1}{4}$ tons, £13. 10s. per ton	438	15	0
Oil recovered by filtration	17	4	7
	£501	18	4

APPENDIX 2.

Adjustment of figures given in Appendix 1 to bring same in line with our introduction, and taking the selling price of sulphate of ammonia as £12. 10s. per ton instead of £13. 10s.

	£	s.	d.
Running cost, as shown by Hollins Mill figures	1,038	17	0
Add for 9d. extra on 1,100 tons of coal	41	5	0
10 per cent. interest and depreciation on present cost of engine, auxiliaries, gas plant, and exhaust boiler, say, £7,250	725	0	0
8 per cent. on buildings and foundations, say, £1,600	128	0	0
	£1,933	2	0

	£	s.	d.	£	s.	d.
Brought forward				1,933	2	0
Credit—As shown by Hollins Mill figures	501	18	4			
Less £1 per ton for sulphate, showing selling price as £12. 10s. per ton	32	5	0			
				469	13	4
				£1,163	8	8

Take b.h.p. as 670

B.h.p. hours = 55×50×670 = 1,842,500

Cost per b.h.p. hour = ·19d.

At 90 per cent. generator efficiency this power equals 1,257,651 kw.-hours. Taking cost of generator as £720, 10 per cent. on same increases net running cost to £1,535. 8s. 8d.

∴ Cost per unit at terminals = ·298d.

APPENDIX 3.

Annual power estimate for a gas power set, suitable for an average weaving shed, comprising 250 normal brake horse-power gas engine, capable of taking at least 10 per cent. overload, coke suction-pressure gas plant, with all usual and neces sary auxiliaries and connections, foundations, and buildings.

Capital Costs.

Gas plant	£450
Engines and auxiliaries	1,700
Exhaust boiler	200
	£2,350
Buildings and foundations	£700

Dr. *Running Cost Account.*

To 385 tons of coke at 13s.	£250
,, Oil and stores	35
,, Mechanic (part time)	75
,, Labourer	65
,, 10 per cent. interest and depreciation on £2,350	235
,, 8 per cent. ,, ,, ,, £700	56
,, Maintenance and repairs	25
	£711

Cr.

By 900,000lbs. of steam raised for mill heating by exhaust boiler = say, 60 tons of coal at 11s.	33
Net running cost	£708

687,500 b.h.p. hours for £708 = ·248d. per b.h.p. hour.

APPENDIX 4.

Annual power estimate for a gas power set suitable for an average spinning mill, comprising 600 normal brake horse-power gas engine, capable of taking at least 10 per cent. overload, Mond water-cooled gas plant, with all usual and necessary auxiliaries, foundations, and buildings.

Capital Costs.

Gas plant	£1,200
Engine and auxiliaries	3,700
Exhaust boiler	310
	£5,210
Engine-house and foundations	£1,100

Dr. *Running Costs.*

To 920 tons of coal at 11s.	£506
,, Oil and stores	80
,, One mechanic	100
,, Two labourers	130
,, 10 per cent. interest and depreciation on £5,210	521
,, 8 ,, ,, ,, ,, £1,100	88
,, Maintenance and repairs	52
	£1,477

Cr.

By 2,000,000lbs. of steam = 300,000lbs. of coal, raised by exhaust gases, available for mill heating, &c., say	75
Net running cost	£1,402

1,650,000 b.h.p. hours for £1,402 = ·2d. per b.h.p. hour.

APPENDIX 5.

Cost scheme for large textile works, doing spinning, weaving, dyeing, and bleaching.

Electric Transmission.

Day load averages 3,500 b.h.p. } Total annual b.h.p.
Night load averages 500 b.h.p. } hours, say, 12,000,000.

Capital Outlay.

One Mond recovery gas plant and auxiliaries for 4,000 b.h.p.	£13,000
Three gas generators of 1,200 b.h.p. each	25,000
One gas generator of 600 b.h.p.	4,000
Four exhaust boilers, fittings, and connections	1,300
Auxiliaries, starting plant, pumps, engine-house crane, switchboard, pipes, &c.	2,000
	£45,300
Engine house, foundations, and buildings	£3,700

Running Costs.

7,500 tons of coal at 11s.	£4,125
Oil and stores	400
300 tons of acid at 35s.	525
Bags for and packing sulphate	100
One chief engineer	150
Three driver mechanics	300
Seven labourers	455
Maintenance and repairs of engines and plant	500
10 per cent. interest and depreciation on £45,300, machinery	4,530
8 per cent. interest and depreciation on £3,700, buildings, &c.	296
Gross running costs	£11,381

Credit—

By 300 tons of sulphate of ammonia at £12. 10s.	£3,750	
By 300 tons of tar at 12s. 6d.	187	
		3,937
Net running cost		£7,444

Cost per unit power.

12,000,000 b.h.p. hours for £7,184 = ·149d., or 8,056,800 kw.-hours for £7,184 = ·222d. per kw. hour.

OIL ENGINES.

BY FRANK CARTER.

In dealing with the application of the Diesel engine to textile mill driving it is obviously impossible to do more within the time at the author's disposal than indicate the general lines on which the engine could be utilised. Conditions vary, and each case, to be strictly accurate, would require to be dealt with on its merits.

The figures given in the following tables have been carefully compiled from data available from installations in daily service. Allowance has been made in the tables for the provision of steam for heating and manufacturing processes, the figures covering this having been obtained from actual costs, both as regards capital and fuel. The author is of opinion that considerable economy in the fuel cost for the provision of the steam could be effected by the use of the exhaust gases from the engine for feed-water heating, and the use of oil fuel in place of coal or coke for firing the boiler.

It is proposed to take as examples a weaving shed of average size, requiring an engine of 320 b.h.p., and a spinning mill requiring an engine 1,000 b.h.p. The cost of fuel oil is taken at 50s. per ton, and this figure would cover cost of delivery into user's tank. One engineer would be required in the case of the smaller engine, and £100 per annum would cover this; while in the case of the larger engine an assistant might be considered necessary, and an additional £65 per annum is included for this assistant.

The following tables give the costs for both sizes of engine:—

320 b.h.p. DIESEL ENGINE.

Capital Cost for Rope Transmission—

	£	s.	d.
Cost of engine, friction clutch, and rope pulley	2,870	0	0
Oil storage tank, with pump and piping	60	0	0
Low-pressure steam boiler, with 1,400ft. of 2in. steam piping, chimney, and fixing complete	135	0	0
Buildings and foundations	500	0	0
	£3,565	0	0

Capital Charges will be as under—

	£	s.	d.
Interest and depreciation on engine, &c., at 10 per cent.	287	0	0
Ditto, on boiler, tank, &c., at 10 per cent.	19	10	0
Ditto, on buildings and foundations at 8 per cent.	40	0	0
Total per annum	£346	10	0

Running costs, allowing 2,750 working hours per annum, and taking the average load as 240 b.h.p., which allows for a portion of machines standing idle while adjustments or changes are being made:—

	£	s.	d.
Fuel oil, 142 tons at 50s.	355	0	0
Lubricating oil, waste, water, and stores	39	0	0
Repairs and maintenance	10	0	0
Coke for heating (1 ton per week) at 13s.	32	10	0
Wages	100	0	0
Total per annum	£566	10	0
Add capital charges	346	10	0
Total cost per annum	£913	0	0

Or a total cost inclusive of capital charges of 0·33d. per b.h.p. per hour.

1,000 b.h.p. DIESEL ENGINE.

Capital Cost for Rope Transmission—

	£	s	d.
Cost of engine, friction clutch, and rope pulley	8,750	0	0
Oil storage tank, pump, and piping	90	0	0
Boiler, piping, and feed pump for heating	250	0	0
Buildings and foundations	1,200	0	0
Total	£10,290	0	0

Capital Charges will be—

	£	s.	d.
Interest and depreciation on engine, &c., at 10 per cent.	875	0	0
Ditto, on boiler, tank, &c., at 10 per cent.	34	0	0
Ditto, on buildings and foundations at 8 per cent.	96	0	0
Total per annum	£1,005	0	0

Running costs, allowing an average load of 90 per cent. of full load, viz., 900 b.h.p.

	£	s.	d.
Fuel oil, 495 tons at 50s.	1,237	10	0
Lubricating oil, waste, water, and stores	109	10	0
Coal for heating purposes, 150 tons at 11s.	82	10	0
Repairs and maintenance	100	0	0
Wages	165	0	0
Total per annum	£1,694	10	0
Add capital charges	1,005	0	0
Total cost per annum	£2,699	10	0

Or a total cost inclusive of capital charges of 0·26d. per b.h.p. per hour.

In calculating fuel costs the guaranteed fuel consumption for the sizes of engines specified has been taken as the basis, while in the items for lubricating oil, waste water, stores, repairs, and maintenance, actual figures from plants in daily service have been taken.

The above figures relate to the driving of textile factories by means of ropes in the usual way, but, in view of the interest taken in electrical driving, and as the Diesel engine is extensively used for generating electricity, figures showing the cost of generating by means of this engine will no doubt be of interest. In dealing with such costs, the author proposes to take exactly the same conditions, so that the figures will be readily comparable, but does not propose to take into account the provision of steam for heating and manufacturing processes, as the cost of this would be the same whether the power were purchased from a public supply or generated on the premises. Also it is intended to deal with the generating plant only, leaving the distribution of electric power to the author of the paper on electrical driving. In the case of the spinning mill it is proposed to divide the power into two units of 500 b.h.p. each instead of one unit of 1,000 b.h.p. This will increase the capital cost somewhat, but the compensating advantages would counterbalance this, while the running costs would be the same

320 b.h.p. DIESEL ENGINE WITH ALTERNATOR.

Capital Costs—

	£	s.	d.
Engine and alternator complete	3,244	0	0
Oil storage tank, with pump and piping	60	0	0
Buildings and foundations	500	0	0
Total	£3,804	0	0

Capital Charges—

	£	s.	d.
Interest and depreciation on engine and alternator at 10 per cent.	324	8	0
Ditto, on tank, &c., at 10 per cent.	6	0	0
Ditto, on buildings and foundations at 8 per cent.	40	0	0
Total capital cost per annum	£370	8	0
Add running costs as before, except coke for heating	534	0	0
Total cost per annum	£904	8	0

Taking the generator efficiency as 92 per cent. at full load, and 90 per cent. at three-quarter load, the cost per unit with an average load of three-quarters of full load would be 0·49d.

TWO 500 b.h.p. DIESEL ENGINES, WITH ALTERNATORS.

Capital Costs—

	£	s.	d.
Two 500 b.h.p. engines and alternators complete	10,280	0	0
Oil storage tank, with pump and piping	90	0	0
Buildings and foundations	1,200	0	0
Total	£11,570	0	0

Capital Charges—

	£	s.	d.
Interest and depreciation on engines and alternators at 10 per cent.	1,028	0	0
Ditto, on tank, &c., at 10 per cent.	9	0	0
Ditto, on buildings and foundations at 8 per cent.	96	0	0
Total per annum	£1,133	0	0
Add running costs as before, except coal for heating	1,612	0	0
Total cost per annum	£2,745	0	0

Taking the efficiency of generator as 92 per cent. at full load, and allowing an average load of 900 b.h.p., the total cost per unit would be 0·39d.

It should be noted that the Diesel engine is a self contained power plant, and no auxiliaries requiring attention by stokers or other labour are required to enable the engine to drive the productive machinery, consequently the number of men engaged in the running of the plant can be reduced to a minimum. Another matter which appears to the author to be worthy of consideration is the amount of space required for storage of the different kinds of fuel. For instance, a 30ft. by 8ft. 6in. boiler shell would hold about 30 tons of oil, sufficient fuel to run the larger plant referred to above at full load for about three weeks.

The main advantages of the Diesel engine may be summarised as follows:—

1. Its economy in fuel consumption and entire absence of stand-by losses.

2. The fuel used is safe, cheap, and the storage of same occupies little space, enabling users in case of necessity to meet such an event as, say, a transport strike, without inconvenience and without the risk of the fuel deteriorating in heat value due to exposure. The flash point of the oil is about 200° Fah., consequently there is no risk from fire or spontaneous combustion.

3. The freedom of the engine from pre-ignition or, as it is commonly expressed, back-firing, the reason for such freedom being that air only is compressed, and not a mixture of air and oil or air and gas. This fact eliminates one of the most frequent causes of breakdown in other internal-combustion engines.

4. The absence of vaporisers, carburetters, and ignition devices. These in other forms of internal-combustion engines are frequently a source of trouble.

5. The engine can easily be started up, 1½ to 2 minutes being sufficient to get the engine on full load. There is no warning up or other preparation, the engine being started on compressed air.

6. Being self-contained, it is compact, and the absence of noise, vibration, smell, smoke, or fire risks makes the engine eminently suitable for use in congested areas and business premises.

ELECTRICAL POWER.

BY J. F. CROWLEY, B.A., M.SC.

Electricity to the textile manufacturer means one of two things. It is:—

(1) A means of transmitting and distributing the power generated at the shaft of a prime mover in his own generating station, or

(2) A source of power in itself when he buys it at so much a unit from an outside supply company, and measures it as it enters the factory.

In the second case only does it pretend to anything like competition with the subject matter of the previous papers, and this in itself perhaps formed the principal source of difficulty in deciding how to treat it.

The method of treatment finally adopted has been to consider first the general case for electrical driving as opposed to the other methods of transmission and distribution adopted for textile work, follow this up with a consideration of the plant required, whether private generation or public supply be decided on, and conclude with the case for the public supply company as usually put forward.

Advantages.— The case for electrical driving rests broadly on—

(*a*) Steadiness of drive, resulting in higher maintained speeds, increased production, and improved quality of material.

(*b*) Specific advantages on the adoption of individual drive resulting in still greater production and improvement in quality.

While the question of speed variation will be treated mainly from the point of view of certain machines, the driving of which has received special attention from electrical engineers during the past few years, it will, of course, be understood that this question is of equal importance in the case of other machines installed in a textile factory, and that the main arguments put forward hold here also.

Now, it is very difficult to convince the average manufacturer that with the ordinary mechanical transmission, whether rope, gearing, line shaft, or belting, or a combination of these, serious fluctuations in speed occur, and that when they occur they affect production and quality to any marked extent. The first is due possibly to the fact that rapid fluctuations of the amplitude usually met with cannot be perceived without the use of special instruments, and the second to failure to see that yarn forms a sensitive detector of these fluctuations, which for a given amplitude are the more destructive the shorter the time in which they take place, and the closer therefore they approach to "hammer action." It is interesting to note that the more nearly is the latter condition fulfilled the more difficult is it to detect the fluctuations with unaided human faculties.

Mule Spinning.—The mule is the worst offender in the textile mill so far as speed fluctuations are concerned, as the following tachograph readings taken by Mr. Woodhouse will show:—

Mule Countershaft—	Max. speed range.
Mechanical drive	25 per cent. of mean speed.
Individual electrical motor drive, direct current	17 ,, ,, ,,
Individual electrical motor drive, alternating current	6 ,, ,, ,,

The power curve of a mule is a peculiar one, the load showing peaks which may be many times the average falling away during a portion of the cycle to a value much below the average. From one of these power curves the result on mechanical drive could be imagined were it not clear from the tachograph readings given above. Ordinarily the mule load in a mechanically-operated mill affects the running of every machine in any way connected with the shafting from which the mules are operated, and this is actually a principle in the laying out of spinning mills. The momentum of the engine and of all shafting, &c., connecting the mules to the engine is depended upon to steady the drive of the mules themselves, and since, of course, no energy can be given to or taken from a revolving mass without altering its speed, we have here a fruitful source of trouble. On electrical drive mules may either be group or individually driven. Important principles to be borne in mind are that, as far as possible, constant speed should be maintained during the "draw" or the actual spinning portion of the mule cycle, and that a given variation in speed where mules are grouped for mechanical drive or electrical drive is liable to be far more serious than a variation of similar range with individually driven mules. With individual drive the speed fluctuations would naturally result from the variation in load of the mule itself, and would therefore follow the cycle of operations of the mule.

In general it may be said that group electrical driving is better than mechanical driving, particularly from a point of view of the mill as a whole, and that individually-driven mules give an increased production of about 5 per cent. over group or mechanically-driven machines, even when the very simple expedient of merely belting an ordinary 3-phase motor of suitable size and of good regulation direct to the mule countershaft is adopted. A considerable saving in power is one of the special features of the individual drive.

Ring Spinning and Doubling.—For the driving of ring spinning frames electricity has peculiar advantages, and motors of the single-phase commutator and the 3-phase commutator type have been developed for this purpose. Owing to well-known peculiarities, with a ring frame driven at constant speed the yarn is subjected to varying tension, and as the speed at which the frame can be run is determined by the maximum tension the yarn will stand, the speed must be such as to prevent this tension being exceeded at any moment, and consequently with a constant speed drive considerable loss in production occurs. This trouble is well recognised, and numerous attempts have been made to meet it by mechanical means. The majority of these consist in the employment of 2-speed devices enabling a low speed to be provided for the forming of the base of a cop when that formation is used, and a higher speed when the base is formed. This does not, however, by any means meet the case, and the only satisfactory solution, so far, has been the electrical one, which gives not only a low speed during the forming of the base, but also an automatic variation of the speed during the cyclic movement of the ring rail.

The following tests were carried out on a ring doubling frame now on the mains of the Lancashire Electric Power Company, before and after conversion to individual driving:—

Ring Doubling Frame—	Max. speed range.
Mechanical drive	6 per cent. of mean speed.
Individual electrical motor drive	5 ,, ,, ,,

This shows clearly the advantages of the individual drive, and it may be said generally that constant-speed motors are usually employed for the electrical driving of these machines.

Weaving. — To consider now the case of looms. A weaving shed may have a load factor of from, say, 30 per cent. in the case of some looms to as high as 95 per cent. in the case of automatic looms, and the shed "efficiency," as understood in the trade, is merely this load factor, and is not necessarily a criterion of the absolute production of the looms themselves. The efficiency of a loom as the term is understood in engineering circles, is a direct function of the loom speed and of the load factor. The speeds at which mechanically-driven looms can be run can be increased by group electrical driving, and to a still greater extent by individual electrical driving, and the load factor can be improved to a certain extent by group driving, owing to the steadier speeds causing fewer breakages, and to a remarkable extent by individual driving, owing to the prompter starts obtainable.

The following test results, which are self-explanatory, are instructive, and illustrate the first part of the case for electrical driving, so far as weaving sheds are concerned:—

	Max. speed range.
I.—Engine	5·5 per cent. of mean speed.
Loom line shaft (near belt drive)	9 ,, ,, ,,
Ditto (middle)	12 ,, ,, ,,
Ditto (end)	16·5 ,, ,, ,,
II.—Loom line shaft (group electrical drive)	6 ,, ,, ,,
III.—Loom (individual electrical drive)	2 ,, ,, ,,

Tests I. and II.—Mr. W. B. Woodhouse.
Test III.—Taken for this paper.

Perhaps the principal lesson to be gathered from these figures is the steady manner in which the speed fluctuations

grow worse as the distance from the engine increases, and this is confirmed by other tests. In a Yorkshire mill it was shown that for a 3 per cent. variation in engine speed 20 per cent. variation occurred on the line shafting. In a high-class Lancashire mill for a variation in speed of 5 per cent. on the engine shaft the line shaft speed varied 16 per cent.

The question of load factor, or loom "efficiency" as ordinarily understood, is also of great importance, and is, as already pointed out, distinctly improved by the adoption of individual driving. The best proof of this is, of course, an actual test under working conditions in one's own factory, but the following results might be given of a test carried out in a spinning mill* on jute looms to convince the manufacturer of the results it was possible to obtain before individual driving had attained the position it holds to-day. The reed space of the looms varied from 36in. to 72in. and the corresponding speeds from 130 to 112 picks per minute. The looms were changed from the ordinary mechanical drive to individual motor gear drive, and it was found that the average speeds could be raised 9 per cent. without any increase in breakages, the material being improved in quality, and the production increased by from 15 to 20 per cent. The excess of the increase in production over the increase in speed was due to the improved load factor. The test was carried out by an independent authority on behalf of the manufacturer.

To obtain the increased production claimed for individual electrical driving the power taken by the loom has naturally to be increased, and this increase usually takes place as the square of the speed. The proportion the power costs in any textile factory bear to the total running costs is, however, very small, being stated in the case of woollen mills to be from 2 to 5 per cent. of the total costs, and consequently the power increase referred to will have little effect on the actual cost of the product. For Lancashire mills I was able to show†, assuming figures based on the Board of Trade returns to hold true for an individual case, that a 10 per cent. increase in production actually resulted in a 30 per cent. increase in profits after full allowance had been made for the increase in power costs referred to.

Generators.— From the consideration given to the special advantages to be obtained from the individual driving of certain electrical machines it will naturally be concluded that in the use of individual motors lies a good deal of the case for electrical driving, and consequently the textile manufacturer contemplating an electrical installation will naturally select a type of current that will be suitable for the special individual motors described. Motors for the individual driving of mules are almost invariably 3-phase, the unsuitability of the direct-current motor being well shown by the speed fluctuation of a mule driven by such a motor. Motors for driving ring spinning and doubling machines may be either 3-phase, single-phase, or direct-current, but the two former are the more suitable; of the variable-speed type for ring spinning, and the constant-speed type for ring doubling. For looms, 3-phase or occasionally 2-phase motors are used. The manufacturer then will install 3-phase generators of standard voltage and standard frequency. Direct current has, it should, however, be mentioned, a field for the driving of printing machinery for which direct-current motors, owing to their adaptability to large variations in speed, are specially suitable. Three-phase and single-phase commutator motors and motors of the pole-changing type are also used for this purpose. As to the speed of generator, this will, of course, depend on the choice of prime mover, and an illustration is shown on a generator suitable for turbine drive, two for slow-speed engine drive, and one for rope driving from a main shaft for a mill extension. A voltage of 500 volts and a frequency of 50 periods are now common in the textile districts, but it should be pointed out that several large power supply companies standardise on 400 volts, as this leaves single-phase current at 230 volts available for lighting. For a weaving shed it may be added that a voltage of 200 is suitable, since the building of small motors for a higher voltage means a somewhat lowered efficiency and increased manufacturing cost. As requirements vary considerably according to special conditions and market prices fluctuate, it is impossible to give costs that would be of practical use except as a rough guide to capital expenditure, and it is in this sense only that the following figures are given.

TABLE I.—*Turbo-Alternators.*

Kw.	Speed.	Volts.	Freq.	Alternator Efficiency.	Prices. Alternator without bearings.	Prices. Turbine and bed-plate, &c.
	r.p.m.			per cent.	£	£
250	3,000	220 3000	50	85	700	904
500	..	440 6600	..	90	850	1,322
1,000	..	..	..	92·5	1,050	2,200
1,500	..	..	..	93	1,350	2,800
2,000	..	..	..	93·5	1,650	3,200

TABLE II.—*Reciprocating Sets.*

Kw.	Speed.	Alternator Efficiency.	Prices. Alternator and Exciter.	Prices. Condensing Plant and Engine.
	r.p.m.	per cent.	£	£
100	500	90	320	580
250	375	92	440	820
500	300	92	800	2,200
750	250	93	1,000	4,000
1,000	220	93	1,500	5,000
1,500	230	94	1,650	7,850

Turbo-alternators are finding increasing favour for textile driving, and their use is every day extending. Owing to the exacting nature of mill work it is always desirable to have a stand-by or a spare rotor provided.

Outside Supply.—In deciding whether to take power from an outside supply company a number of factors have to be taken into consideration, and it is always desirable when in the area of such a company to obtain electrical rates from them for comparison with the estimated cost of private generation before deciding on the course to adopt. In a work first published in 1899, Prof. Perry makes the following statement: "A not unusual charge of an electrical supply company is 5d. per Board of Trade unit." Now, having gone to some trouble to ascertain the rates prevailing in textile areas, I think the following remarks fairly represent the case: In the most competitive areas where the demand is high and better opportunities exist for the power company, ·5d. per unit or one-tenth of the figure given by Prof. Perry is regarded to-day as a good competitive figure for a fair load on the usual cotton mill load factor of 25 per cent. to 29 per cent. For particularly good loads from the station engineer's standpoint figures of ·45d. and ·4d. per unit are quoted, and in one area some manufacturers actually obtain current at ·3d. per unit. But it is only fair to state that, in the author's opinion, this figure must be regarded as rather special, and the remarks made about ·5d. per unit taken exactly as given. The price at which it pays to take current from outside depends altogether on the individual case, and current at ·6d. and ·75d. and even higher may very well pay the manufacturer in particular cases.

The system of supply on restricted demand is in force with some supply companies, and manufacturers with existing plant may find it an advantage to drive, say, preparing rooms with current at a low rate on this basis, the understanding being that the supply is cut off at a definite hour during a certain period of the year.

The conditions that affect cost of power and would cause a variation in the figures quoted are frequently not understood by the manufacturer, who does not always perhaps appreciate the important influence of the nature of the load and of the load factor on generating costs.

* Messrs. Blutchen and Sons, Vetschau.

† Paper read before the British Association of Managers of Textile Works, Manchester, March 30th, 1912.

The following claims are usually made by public supply companies:—

(1) Economy in working due to

(*a*) Larger units;

(*b*) Units run more nearly on full load and therefore at a higher efficiency;

(*c*) Greater ease with which modern labour-saving devices are installed;

(*d*) Saving in general attendance costs;

(*e*) Lower percentage capital costs since position of plant is not determined by position of load but by cheapness of land, &c.

(*f*) Stand-by plant carried at a lower percentage capital cost.

(2) That in the case of a new mill more capital can be spent on remunerative machinery.

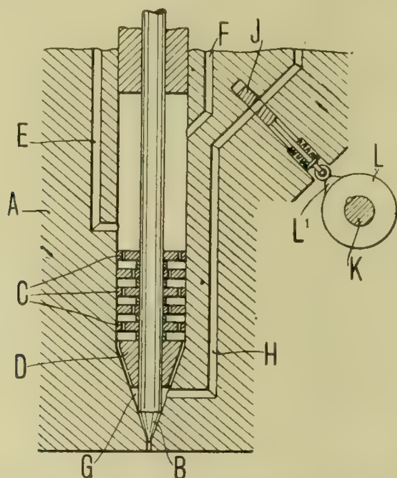
(3) Elimination from customer's consideration of all matters not directly concerned with his business, such as engineering details, fuel costs, &c.

(4) Facility with which any portion of a mill can be run without running main generating plant.

(5) The important consideration that the power company's engineers are always at their customers' disposal when engineering problems arise.

FUEL-INJECTING APPARATUS FOR INTERNAL-COMBUSTION ENGINES.

For the reliable working of a fuel injecting device controlling the supply of a fuel which is difficult of ignition, such as tar oil, for example, it is necessary, even when the engine is running on a light load and under which circumstances the fuel pump supplies a small quantity of fuel to the nozzle, that there shall always be some fuel in the annular space above the seat for the needle of the fuel valve when the needle is opened, as otherwise the opening of the needle prior to the entrance of the freshly supplied fuel will admit cold compressed air into the cylinder which will prevent ignition from taking place. The fuel injecting apparatus illustrated



Fuel Injecting Apparatus for Internal-combustion Engines.

herewith, the invention of Messrs. Krupp, of Kiel-Gaarden, Germany, has been designed with a view to ensure certain ignition even when the engine is running on a light load.

The fuel injecting valve proper is of the usual well-known construction, and consists essentially of the valve cage A, the fuel needle B, the atomising plates C, and the atomising cone D. The fuel is supplied through a passage E and the compressed air through a passage F. The annular space G lying immediately above the seat of the needle is connected with a space which is under a lower pressure, such, for example, as the outer air, by a passage H, in which there is arranged a cut-off valve J. This valve J is so operated from a shaft K, the cam shaft, for example, by means of a cam disc L and a cam L_1, that after the supply of fuel by the fuel pump is completed and before the fuel needle B is opened, it is opened for a short time, and then immediately closed again. This periodical opening of the passage H allows a movement of the contents of the nozzle starting from the point of the injection of the compressed air and directed towards the annular space G. If, therefore, the whole of the fuel be blown out of the annular space G when the engine is running under a light load, the compressed air contained in this space can escape through H and its place will be taken, provided the time during which the passage H remains open and the dimensions of its opening be properly arranged, by fresh fuel delivered through the atomising plates C and the cone D, and which fuel, after the passage H has been shut off, will then be the first to enter the cylinder when the fuel needle is opened, and will effect ignition with certainty. As such ventilation of the annular space G is not necessary when the engine is running under a heavy load, because the whole of the fuel is not entirely blown out of the nozzle, the operating mechanism of the cut-off valve J is so constructed that the passage H is only opened when the engine is under a load which falls below a definite amount, which latter is determined by experiments.

For the purpose of economising compressed air, the operating mechanism is so arranged that when the engine is running under a heavy load the passage H is at first opened only a very small amount, and this amount of opening or time of opening of the passage H is increased gradually up to a maximum, when the engine is running on no load at all. This is effected by constructing the cam L_1 in the form of a cam of variable lift and moving the cam disc L upon the shaft K by the governor, in such a way that when the engine is running under a heavy load the passage H is at first opened cylindrical part of the cam disc and gradually runs up the obliquely ascending cam as the load decreases. As it is not always possible to prevent some fuel being carried along when the passage H is opened, care must be taken that such fuel can be separated again. For this purpose the free end of the passage H is directed against an inclined baffle surface, down which the fuel carried along runs, so that it can be returned to the fuel tank again.

Trials of a Clyde-built Destroyer.— H.M.S. "Lurcher," one of the special destroyers of the "Firedrake" type ordered from Messrs. Yarrow & Co., Scotstoun, had a most successful official full-speed trial on the 13th inst. on the Skelmorlie deep water measured mile. During a continuous run of eight hours she attained a mean speed of 35·34 knots, thus exceeding the contract speed of 32 knots by 3·34 knots. The vessel is 255ft. long and 25ft. 7in. beam. She is propelled by Parsons turbines driving two shafts, steam being supplied by three Yarrow water-tube boilers fitted with the firm's latest feed-heating device. The high speed attained by the "Lurcher" shows that that vessel is one of the fastest destroyers yet built.

Oil Fuel for Steam Raising.—In the course of a lecture on this subject, delivered at the Oil Engineering Exhibition, Olympia, Mr. J. J. Kermode said that the recent coal strike had done more to emphasize the value of liquid fuel than years of patient advocacy and toil. Many factories had to resort to oil fuel to keep going, and in every case the boilers were expeditiously fitted for the use of liquid fuel without altering the furnaces as arranged for coal. The lesson of the coal strike would not be readily forgotten, and the heads of many municipal power stations had under consideration the advisability of being able to use liquid fuel should the necessity arise in the near future. The British Government, Mr. Kermode pointed out, had recently appointed a Royal Commission to go into the question of the use of oil fuel for the Navy, and this had caused a wider interest to be taken in oil fuel than heretofore. Incidentally, he mentioned that the "Titanic" enquiry had resulted in certain recommendations in ship design which were bound to have an influence on the use of oil for the propulsion of our greatest liners. As a result of the lamentable happening to the "Titanic," the newest White Star liner would be built with a cellular double bottom, and as this would absorb such an enormous cubic space which would not be available for cargo, the obvious inference was that the space could be utilised for oil fuel.

A NEW PHOTO-MECHANICAL ENGRAVING PROCESS WITH STARTLING POSSIBILITIES.

DURING recent years great improvements have been made in many of the photo-mechanical engraving processes employed in the production of line and half-tone illustrations with which readers of technical journals are familiar. The accuracy with which these can be reproduced and modified in size from originals would apparently leave little room for further invention or improvement. One of the exhibits at the exhibition of the Royal Photographic Society, which closed on the 21st inst., however, displayed a rather startling development in one direction which, owing to the facilities it appears to afford for fraudulent use in the reproduction of printed banknotes and bonds printed from intaglio engraved plates—as many foreign bonds and notes are—deserves the serious attention of bankers and Government authorities. The process is the invention of Mr. A. E. Bawtree, of Manor Park Road, Sutton, Surrey. Although we are not in a position to describe the exact modus operandi, a description of the exhibits shown and such particulars as Mr. Bawtree has furnished us are sufficient to show the importance of the invention, since it permits of the reproduction of steel and copper plate engravings with the utmost ease and cheapness.

The process consists of two entirely novel operations. Instead of taking a negative of the original by means of a lens, and from that printing the necessary positive, the whole of the actual ink of the original is transferred bodily from its paper support on to a glass plate, without the addition or loss of a particle of pigment, and thus gives a printing transparency incomparably superior to the most perfect one obtainable by the purely photographic operations. From this perfect transparency a copper plate is printed (or a steel plate, where such may be preferred) by a method which excels anything else, in that it yields printing lines of full strength of the most delicate hair lines in the original, while it does not add anything to the vigour of the stronger portions of the work, and in this way preserves absolutely mechanically the exact tone values of the original.

In the transparency section of the exhibition were shown one of these engravings, on its glass support, which afforded an excellent idea of the perfection of the transfer. The transparency was eminently adapted for use in the photogravure process, while the original, after serving its purpose, could be put back again on to paper.

The inventor points out that it would obviously be inexpedient to publish at once the details of this process, as there are still in circulation a large number of plate-printed banknotes and bonds, and, owing to its extreme simplicity, and the inexpensiveness of the appliances required, such publication would lead to wholesale forgeries. But the process has important commercial applications, for the employment of which arrangements are in progress. As the details will inevitably become known sooner or later, bankers, financiers, and others will be well advised not only to avoid steel and copper-plate printing in future issues of monetary documents, but, without undue delay, to replace such as they have at present in circulation by a more secure class of work. This warning is particularly necessary in the United States, where the New York Stock Exchange regulation, requiring all bonds to be plate printed, is still in force.

It is immaterial what colour the original engraving is printed in, or what the chemical composition of the inks employed, as the image, when once on the glass, becomes for all practical purposes a photographic one. In this form it can be stripped, reversed, or intensified as required, and no protective colour grounds, whether printed direct from plates or by means of blocks, stone, off-set, or any other medium, render steel or copper-plate printed matter secure against forgery.

Plate-printed matter has hitherto been regarded as possessing security for several reasons:—

(1) If the forger attempts to re-engrave the work he must obtain costly and elaborate machinery.

(2) If he tries to photograph the work, he has to equip himself with a good process camera, lighting arrangements, and other paraphernalia of the process photographer.

(3) In either of these cases he must deal with one of a very few firms who specialise in such matters, who will keep a record of his purchases, and who can therefore readily put detectives on his track.

(4) The plant, in whichever way the forger sets to work, would incriminate him if found in his possession, yet, being costly and difficult to obtain, he cannot afford to destroy it as soon as he has made a set of plates, in case he wants it again.

(5) The market for such goods offered second-hand is limited, and attempts to sell would call as much attention to himself as the original efforts to buy.

(6) Both methods of reproduction are very imperfect, so that the forger must have the assistance of a skilled engraver and banknote artist, in order to bring his work up to a negotiable standard of excellence. All such men have necessarily served an apprenticeship and are well known to their fellows. This very much limits the range of the search when the authorities are upon the track of a forger.

It is evident from Mr. Bawtree's discovery that none of the above six protective points will henceforth be effective, since:—

(1 and 2) No expensive or elaborate machinery or equipment is required; even though the process is strictly photographic, no camera at all is used.

(3) All materials and apparatus are of the very simplest. The total number of chemicals required in order to carry out the operations from the first treatment of the original engraving to the completed steel or copper plate is only 12, as small an outfit as would be found in the hands of the majority of ordinary photographic beginners. Everything is readily obtainable from dealers in materials for the use of the amateur photographer, and would attract no suspicion to the owner either in purchasing or possession.

(4) The whole plant is extremely cheap and compact. Everything necessary for producing a set of banknote plates, or the plates for the talons and coupons of a set of bonds, together with a full stock of all requisite materials, costs about £2. 10s. The whole can be packed in one ordinary Tate sugar box. The forger need therefore experience no difficulty in concealing the fact of its possession, while he can easily afford to scrap the whole, if necessary, as the issue of a single forged £5 note would more than repay him.

(5) There is a ready sale for second-hand photographic appliances of ordinary type, so that the forger can dispose of the plant at no great loss in order to avoid suspicion, should he fear such from its possession.

(6) The method of reproduction is so perfect that the work of the engraver and artist is dispensed with. A straight pull from the purely mechanically produced plate gives a quite negotiable forgery. Even the printing appliances would call forth no suspicion on their possessor. The inks are readily ground in the small quantities required on a piece of glass with a palette knife, while an ordinary domestic wringing machine answers well as a plate printing press for small plates.

As some alarm may possibly be excited by this description respecting the security of Bank of England notes, it may be added that the process applies entirely to the reproduction of steel and copper-plate printing, and as banknotes are surface printed, they are safe from reproduction by Mr. Bawtree's method.

Personal.—It is officially stated that Mr. G. J. Carter, one of the local directors of Messrs. Sir W. G. Armstrong, Whitworth, & Co., has resigned his position at Elswick in order to accept a seat on the Board of Messrs. Cammell, Laird, & Co., Ltd., of Sheffield and Birkenhead. He will succeed to the position of managing director of the shipbuilding and engineering works at Birkenhead recently resigned by Mr. R. R. Bevis. It is also announced that Mr. James H. Boolds, shipbuilding director at Messrs. Vickers, Barrow Works, is retiring, but his services will be retained for duties connected with the establishments in which the company is interested at home and abroad.

DEVELOPMENT IN THE USE OF GAS FOR HEATING AND POWER PURPOSES.*

BY EDWARD B. ROSA, PH.D.

THE use of gas for heat and power has rapidly increased in recent years. This is partly due to a reduction in the price of gas and to improvement in the service rendered by gas companies, and partly to the improvement of gas appliances in the direction of greater convenience and efficiency and to the invention of new appliances for the accomplishment of many results in new ways.

Coal Gas.—The first recorded suggestion of the use of gas for fuel was in the patent taken out in England in 1805 by F. A. Winsor for a process of "extracting inflammable air" from coal. The product was to be applied to heating as well as to lighting; but in spite of his great enthusiasm, Winsor was not successful in bringing about the utilisation of gas for fuel, and little was done along this line until about 1825, when the first gas cooker was invented. From that time until about 1880 development was very slow. One important invention, however, was that of Delbruck, who placed one tube inside another, using one for the gas and the other for the passage of the air, mixing the two at the point of ignition.

What are usually called bunsen burners in connection with gas stoves are a modification of bunsen burners, invented by Thomas Fletcher, of England. The true bunsen consists simply of the familiar open tube of the laboratory with the gas nozzle and air ports at the base. Fletcher was the first to use a cap to diffuse the flame and reduce its liability to flash back.

The last 30 years have witnessed a wonderful development of every kind of heating appliance, and the most modern gas-lighting units make use of the gas for heating solid materials to incandescence instead of deriving the light from the luminosity of the flame itself.

Acetylene Gas.—Although acetylene gas was discovered in 1836, it was not until 1892 that its commercial development was made possible by Willson, who discovered a method of producing calcium carbide in large quantities. The application of acetylene to heating and power has been very recent indeed, and the use of acetylene and oxygen in the blowpipe has produced almost the highest temperature known to chemistry—a temperature approximating that of the electric arc, probably above 6,000° Fah. Through this means welding has been successfully accomplished and several other important industrial applications have been found. Large steel bridge girders can thus be cut apart with ease. There seems to be a great field open for the oxy-acetylene flame.

Natural Gas.—The first use of natural gas in the United States was probably in Fredonia, New York, in 1821, and before long it was being used in rare instances for heating purposes. In 1859 Drake drilled the first oil well, and, as natural gas was found in abundance, its use was greatly increased. At first it was only used near the wells, but from time to time some enterprising individuals would run pipes from near-by wells to their homes and villages. At first it was used in the coal or wood stoves for cooking and heating, and at the wells for power by piping it directly to the cylinders of steam engines and using its expansive force as a substitute for steam. The waste of gas for many years was very great, no interest being taken in making economical appliances, or even in turning the gas off when not wanted.

The first company formed exclusively for the distribution of natural gas was in 1872 in Titusville, Pennsylvania, since which time its use has become quite extended. As a fuel, natural gas is burned in almost exactly the same way and with almost the same appliances as manufactured gas. It may be used in the ordinary gas range, hot plate, water heater, or other gas-burning appliances, the only change necessary being that because of the higher pressure the gas orifices should be smaller, and because of the higher heating value less gas is necessary to produce the same results. Furthermore, the application of natural gas to coal-burning installations of all kinds is very simple and, as a rule, very efficient.

* From an address delivered at the celebration of the centenary of the introduction of gas as an illuminant, under the auspices of the American Philosophical Society, the Franklin Institute, the American Chemical Society, and the American Gas Institute, in the hall of the Franklin Institute, Philadelphia, April 19th, 1912.

Producer Gas.—Producer gas, the gas made from cheap fuels, using oxygen from the air to produce carbon monoxide, has come into prominence within the last 12 years. Although only a few scattered installations are reported as having been made in the United States prior to 1900, there are now probably 200 or more plants together having an output of over 50,000 h.p.

The two principal types of gas producers are the suction plant, used for small units below 300 h.p. capacity, and the pressure plant used for larger outputs. The suction plant receives its name from the fact that the engine develops its charge of gas in the producer by means of its own suction stroke. The pressure plant develops its gas under a slight pressure due to the introduction of an air and steam blast, and the gas is stored in a holder until it is required by the engine.

In Europe producer gas has been applied much more generally than in this country, but it is fast working its way into the industries here, such as glass furnaces, brick, pottery and terra-cotta kilns, lime and cement kilns, sugar-house char-kilns, silver chlorination and ore-roasting furnaces, &c. Although its use is accompanied by some dangers and disadvantages, the facts that it is the cheapest gas made per unit of heat and contains more of the energy originally in the coal than any other, and that it is possible to use very poor fuel in its production, make it a very economical gas when properly applied.

Conditions for Good Combustion.—One of the principal points to consider in the construction of heating appliances is the combustion of the gas. Efficiency, maintenance, and many other important items are largely dependent on this feature. Some of the conditions for good combustion are:—

(*a*) Complete and equal combustion of the gas must be had over every part of the burner and from every opening in the burner.

(*b*) Good mixing of air and gas, and equal proportion of primary air in all parts of the burner, are essential.

(*c*) There must be plenty of secondary air in the proximity of the burners, so that the flames will not be smothered, and good draught through the appliance to carry away the products of combustion.

(*d*) Flames should not impinge on cold surfaces in such a way as to cause incomplete combustion and so waste the heat and perhaps produce carbon monoxide.

(*e*) In those appliances where an adjustable air shutter is used, this shutter should be easily adjustable and yet should remain as adjusted. In those appliances that have a fixed air supply, the spuds should be readily accessible.

Each different form of appliance offers problems of its own, but the observance of these general conditions is important.

Development of Gas Cooking.—In the patent taken out by Mr. Winsor in 1805 for the manufacture of coal gas, we find the first recorded suggestion of the use of gas for cooking. But the actual utilisation of gas for cooking was much later. Our earliest knowledge of a gas stove is to be obtained from a magazine of the year 1825 which described it as a piece of "gas apparatus for cooking by enclosing the circle of gas flames with its reflecting cone in a cylinder of tin, from the top of which a pipe takes off the burnt air." A drawing of the burner was also given, and the writer adds: "A hot-plate has been heated by the gas, and it has also been employed to heat an oven. . . . It cannot be expected to succeed, however, except in the hands of persons whose scientific knowledge enables them to employ it with safety."

For a number of years there seems to have been little done in the way of actual trial, although the geniuses of the time were thinking about it and taking out patents. It is unlikely that we shall ever know who was the first user of gas for cooking, all we know definitely about the subject being that James Sharp, of Northampton, England, demonstrated the availability of gas cooking in his own house about 1830 or 1832, and a year or two later John Barlow, of Islington, London, had an apparatus for roasting, boiling, and steaming in the kitchen of his house. This consisted of a tin oven, around the four sides of which, inside near the bottom, ran a gas pipe, fitted with small burners about 1in. apart; on a stand alongside the oven were two or three rings of piping with burners, and over these were placed the

boilers and saucepans. After this, inventions for cooking by gas became more numerous, although the gas range at first gained very slowly in popularity.

In 1850 James Sharp, then of Southampton, delivered a lecture entitled "Gastronomy," in the course of which he roasted before the audience 34lbs. of beef, 15lbs. of mutton, and 12lbs. of pork, and boiled and steamed 24lbs. of mutton and codfish, four fowls, eight plum-puddings, vegetables, &c., and baked pies and tarts, the whole being done with the expenditure of 156ft. of gas.

In the following year (1851) Alexander Graham, a well-known hotel proprietor of Glasgow, exhibited in the great Exposition in London a gas cooking oven, which was fitted with luminous jets inside. Mr. Graham made and sold a limited number of cookers for hotels and restaurants, but so far the use of gas ovens for domestic purposes was practically unknown.

A stove used in Philadelphia prior to 1860 is still in existence, and forms part of the exhibition upstairs in connection with this Centenary. It has a peculiar boiling burner which consists of a piece of ½in. pipe bent upwards into a sheet-iron truncated cone, containing a perforated baffle-plate of the same material. The upper end of the cone contained a fine wire screen covered with about ½in. of fine gravel.

From this time on until about 1880, the history of the use of gas for cooking was an exceedingly slow development. In 1860 the "Cincinnati Gazette" said: "At present about 100 families are cooking with different kinds of gas stoves." The development has taken a faster pace in recent years and thus has brought us to the present state of efficiency and convenience. The gas cooking range of to-day is distinguished by the following features: The flow of the hot products of combustion from the oven burners is so directed that the food is evenly cooked top and bottom in any part of the oven; air space insulation of the oven walls prevents the loss by radiation of an undue quantity of heat; adjustable air mixers on all burners permit of the complete elimination of soot; the boiling burners are so set that the placing of vessels over them does not smother the flames, or cause incomplete combustion; the boiling burners and their fixtures are easily removed by the cook for purposes of cleaning and are put in place again with equal ease, and all details are aimed to combine efficiency and convenience.

Tests of the relative heat efficiency of gas ranges have been made, but such tests have not been sufficiently standardised so that numerical statements can easily be made. Further tests are desirable, and if greater attention is given to the question of efficiency and economy, it is probable that considerable further improvement will be made by manufacturers.

Gas Water Heating.—About 1825 Robert Hicks took out a patent in England for "Heating water in baths by means of burning spirits of turpentine, or carbonetted hydrogen gas in chambers, in the bath, or in tubes passing through or under them." Up to about 1890 there were really no convenient and economical water heaters. Since then the instantaneous hot-water heater has been developed and this has greatly augmented the use of gas ranges, the one being a very important adjunct to the other. Gas water heating is one of the most important of the domestic uses of gas, and it is very desirable that water heaters be tested systematically and the results of tests made public for the information of users.

Gas Room Heating.—About the year 1833 a patent was granted to one Richard Barnes for heating buildings by the combustion of gas or oil, applying the flame either externally to tubes or chambers through which currents of air were passing, or else placing the flame inside the tubes or chambers.

Peckston, in his "Practical Treatise on the Manufacture of Gas," published in 1841, says: "Coal gas has of late years been applied to the heating of churches, chapels, shops, counting-houses, &c. . . . and has been found to answer the purpose intended." The stove described closely resembled the cooking stove of 1825, except that it was provided at the top with a register instead of the flue.

A form of stove now very popular in England under the name of the "Gas-fire," and consisting of lumps of incombustible material heated to a greater or less degree of incandescence by gas burners so as to resemble a coal fire, was patented by Edwards in 1849. Seven years later, Nathan Defries was granted a patent for a similar device, the "argillaceous material" specified having fastened upon it fibres of asbestos, which, upon lighting the gas, became incandescent. This was followed three years later by a patent granted to Reece for a stove in which the asbestos back was the main feature.

In spite of the limited use of gas for fuel, a company called "The Gas Fire Company" was incorporated in England in 1852. This seems to be the forerunner of the many ill-fated attempts to do a purely fuel business by artificial gas. Room heating is now one of the common uses of illuminating gas.

The Use of Gas for Industrial Purposes.—In 1806 Mr. Josiah Pemberton exhibited various forms of gas lights in front of his factory at Birmingham. He was the first to construct a gas stove, using it for the soldering required in his button factory. About 1840 a Scotch manufacturer by the name of Macintosh made several tons of "cemented" steel by submitting iron at a dull red heat to the action of lighting gas. The carbon for the steel was derived from the gas. In 1857 a patent was granted for the heating of irons for laundry work by means of gas, and in 1859 a soldering apparatus for continuous soldering by means of gas was described in the "Technical Press." This included the use of a blast worked by a foot bellows.

In an advertisement of Elsner, of Berlin, in July, 1859, it was pointed out that there was scarcely a brand of domestic work, of industry, or of business for which a gas cooking or heating apparatus could not be recommended. Thus it is evident that the use of gas for industrial purposes is not of recent origin, and that it has not been brought about through a falling off in the use of gas for lighting, due to the increased use of electricity.

At the Paris Exposition of 1867 there was exhibited singeing apparatus for use in wool works, dye works, and bleaching works. Jewellers were also using gas. Plants for chemical and metallurgical purposes and laboratory ovens were also shown.

About 30 years ago what seems to us a curious method of using gas was considerably in favour. This was its use under boilers for generation of steam for engines up to about 2 h.p. At the Royal Agricultural Societies Exhibition, held in 1879, several forms of such boilers were exhibited.

In 1879 the South Shields Gas Company, an English concern, gave an exhibition of over 300 appliances in which gas was to be used for other purposes than lighting. To-day there are about 1,000 practical applications of gas in the industries, and a conservative estimate places the proportion of gas sold for fuel at one-half the total sales.

Air under Pressure v. Gas under Pressure in Industrial Appliances.—The subject of air and gas under pressure is one that is receiving considerable attention at the present time, although the field has not been as extensively explored as the others that have been described. In England and on the Continent there are a number of companies now operating to furnish gas at high pressure for private establishments as well as for the public street lamps. The result is that in Europe there has been more done with the gas under pressure than in America, while, on the other hand, America has probably made more use of the air blast with low-pressure gas. "The disadvantage of the latter for furnace heating is that the efficiency depends upon the two pressures remaining constant. Experience shows that under working conditions it is too much to expect that these will remain constant, but the main defect in air-blast burners up to quite recently has been that they were badly designed—their mixing arrangements being inadequate. Such gas burners as those recently designed which do away with secondary air and improve the mixing of the air and gas are a great advance on previous designs."

"High-pressure gas should have a great field before it in the industrial world. It can be applied to all heating processes with efficiencies reaching in some cases at least 90 per cent. Its chief charm is its cleanliness and its simplicity; and in by far the majority of cases it compares well in cost with solid fuel."

Processes in which Industrial Appliances are Used.—Some of the processes in which gas has been used in the industries are as follows: (1) Hardening, tempering, and annealing of steel, and the heating of automatic heating machines; (2) melting of base and precious metals; (3) forging and drop forging; (4) welding, brazing, soldering, and rivet heating; (5) developing power and generating steam; (6) boiling liquids

and melting of solids; (7) tire heating, and the heating of mangles and steel rolls; (8) heating japanning and embroidery ovens; (9) air tempering; (10) singeing of cloth; (11) heating branding irons; (12) firing china; (13) melting barium chloride and cyanide of potassium for hardening steels; (14) embossing and stamping presses; (15) heating muffle-furnaces, and assay work, and reducing sweeps; (16) heating oil tempering furnaces; (17) pressing irons, stoves, and machines; (18) heating searing iron; (19) matrix drying in printing; (20) roasting coffee and nuts, and popping corn; (21) sterilising and pasteurising.

These are a few of the many processes that might be mentioned, but they are typical as showing the wide variety of applications of illuminating gas.

Development of the Gas Engine.—The gas engine really dates from the year 1791, when John Barber patented an engine driven by gas obtained by heating wood, coal, oil, or other substance in a retort. After the gases had been cooled they passed through a pump, in which they were mixed with air, to an "exploder." At the orifice of this exploder the gas was lighted, and issued, in a continuous stream of flame, against the vanes of a paddle wheel. This was not only the first gas engine, but the first gas turbine, a form of machine not in existence to-day.

In 1794 Robert Street designed a pump driven by the explosion of turpentine vapour below the motor piston. In 1801 Philippe Lebon took out a patent for an engine to give alternate explosions on each side of the piston. Samuel Brown, in 1823, designed a motor to operate by atmospheric pressure in which he used an explosive gas flame to expel the air from the chamber.

In 1823 L. W. Wright patented his double-acting vertical engine combined with a governor to regulate the speed. In 1838 William Barnet suggested the compression system of gas motor. This experimental period of gas engine research may be said to have lasted for 70 years—1791-1860. In the latter year Lenoir, of Paris, produced the first practical gas engine to work rapidly and silently, with electric ignition by jump-spark.

In the years that have followed improvement after improvement has been made until the amount of coal gas necessary to develop ignition horse-power has been reduced from 100 cub. ft. to 14 cub. ft. and even 12 cub. ft. per hour. Only the principal steps in the development can be mentioned.

In 1861 Million proposed compression and the use of a compression or combustion chamber. In 1862 Beau de Rochas took out a descriptive patent of the compression 4-stroke cycle now known as the Otto.

Otto and Langen exhibited their free-piston atmospheric engine at Paris in 1867, and in 1876 Dr. Otto brought out his famous engine with the Beau de Rochas cycle.

In 1878 and 1879 Mr. James Robson, and in 1882 Mr. Dugald Clerk, patented 2-cycle engines, and in 1884 Atkinson brought out a "differential" type with the strokes of the cycle of different lengths.

In 1890, when the Otto patent expired, many firms who had been making gas engines upon other lines brought out new designs, all working on the Beau de Rochas cycle. This gave a great impetus to the sale of gas engines. With the close of the century came the utilisation of producer gas for power purposes; the manufacture of large-sized units over 600 h.p. by John Cockerill Company in Belgium and by Crossley and the Premier engine in England; the design of the Westinghouse throttling governor; and the Sargeant engine with cut-off governing; the rise of the natural gas engine in large units; and the double-acting gas engine with compression in America.

The two great classes of gas engines to-day are (1) the 4-cycle or "Otto" type and (2) the 2-cycle or "Brayton" type. The former, called also the internal-combustion type, with heating at constant volume, has only one working stroke in four, the four strokes being: Charging, compressing, firing, exhausting.

The 2-cycle type, with heating at constant pressure, usually has two cylinders, one a compressing pump and the other the working cylinder.

A third type of engine which should be mentioned is the cycle with heating at constant temperature, or Carnot cycle. The nearest actual approach to this cycle using gas is the Diesel engine.

GEAR DATA FOR MOTOR APPLICATIONS.

IN the selection or specification of pinions for motors in geared applications, three dimensions must, says Mr. C. W. Drake in "The Electric Journal," be determined, viz., the face, diameter, and pitch. These dimensions vary symmetrically according to the strength required, or, in other words, according to the torque exerted in transmitting power. As the horse-power and speed of the motor in any case determine the torque, it is evident these are the factors determining the proper dimensions of a pinion for the motor. A line of pinions with dimensions increasing symmetrically with the torque will therefore answer the purpose for all combinations of horse-power and speed. Every geared application requires special consideration, since the nature of the service, the shaft diameter, &c., may affect the dimensions of the pinion.

The dimensions for pinion for average conditions of service are given in Fig. 1. This chart is useful in making preliminary estimates or selections of pinions for geared motors. The chart applies without correction to steel pinions only The diameters are considered about standard for the various ratings, although both smaller and larger pinions can generally be used, the limiting size for small pinions being the strength and number of teeth, and for large pinions the pitch-line speed.

For example, to determine the steel pinion for a 5 h.p. motor at 1,200 revs. per minute, find the inter-section of the oblique line marked 5 H *p* with the horizontal line through 1,200 revs. per minute. On the vertical line through this intersection may be found 21·9lbs. torque, 2·3in. pinion face, 3·2in. pitch diameter, and a diametral pitch of 4·85. A 2·25in. pinion face is good practice here, since pinion-face dimensions with fractions smaller than 0·25in. are not commonly used. The diametral pitch is also usually a whole number, except for very large pinions, where half-pitches are sometimes used, so that a pitch of 5 would probably be used in the above case. Since the number of teeth is the product of the pitch diameter and the diametral pitch, the assumed pitch diameter, 3·2in., is satisfactory with the 5 pitch, because it gives a whole number of teeth, that is, 16.

In gear drives the pinion is subject to most rapid wear owing to its smaller diameter. It is as important to have a pinion of good wearing qualities as it is to have one of sufficient strength, and for a pinion of a given material the ability to withstand wear depends mainly, if not wholly, on the width of the face. With a steel pinion and a cast-iron gear the former is usually the limiting factor of life and the latter the limiting factor of strength.

Cast-steel gears are about twice as strong as cast iron, and should be used when the face of a corresponding cast-iron gear would be 4·5in. or more, although the cost is approximately double that of cast iron. With continuous contact all along the length of the teeth, the strength of the gear is approximately proportional to the face and the square of the circular pitch, but gear teeth seldom make such contact until worn down in service. With new gears the whole pressure is brought to bear on the high spots, and stripping may occur before they are worn down; hence the necessity of using the stronger material.

Noise and Pitch-line Speed Limits.—Spur gears ordinarily begin to make a noticeable noise at pitch-line speeds of about 600ft. per minute, but under average conditions may not become disagreeably noisy with pitch-line speeds under 1,200ft. per minute. The amount of noise allowable depends on the noise made by surrounding machinery, on the character of the workmen, and on the nature of the work in the vicinity. A noise that would be unnoticeable in a boiler shop might be exceedingly disagreeable in a shop that was otherwise comparatively quiet. Where noise is not a limiting feature there is no limit to allowable pitch-line speeds, except the increased wear and depreciation of the motor, gears, and driven machine; but depreciation may become a very important factor with high pitch-line speeds, say, 2,500ft. per minute, or sometimes even less. Tests recently made to determine a design for gears that will give the least

noise and yet have sufficient strength and wearing qualities indicate the following facts, other conditions being the same:—

1. Gears having large teeth give forth a relatively greater volume of noise at a low pitch that does not carry far, while gears having smaller teeth give forth a smaller volume of noise at a higher pitch that carries farther.

2. Most of the noise comes from the gear, and not from the pinion or the motor.

3. A gear designed so that it will give a dead sound when struck a blow with a hammer will be the least noisy in operation.

Bronze and Rawhide Pinions.—For equal strength the working face of rawhide pinions must be about 25 per cent. wider than corresponding steel pinions. For quiet operation, only the rawhide should be in contact with the gear, although for high torque motors and for other severe service the gears may be widened to cover the entire pinion, thus making use of the metal flanges. Where steel pinions would make objectionable noise, rawhide pinions should be used if the stresses permit, since the pitch-line speed with a rawhide pinion is limited more by the rapid wear of the pinion than by noise. A pitchline speed of 2,000ft. per minute is considered a fair average limit for rawhide, but 2,500ft. to 3,000ft. per minute may be used under especially favourable conditions regarding attendance, lubrication, absence of moisture, or high temperature, for intermittent service, or where the life of the pinion is not important.

The wear and noise of bronze pinions are intermediate between those of rawhide and steel. Bronze pinions are particularly adapted to conditions where heat and moisture prohibit the use of rawhide. Their cost is about the same as rawhide.

Conditions for Noiseless Operation.—Rigid and massive supports and close-fitting bearings for both the motor and the driven machine are conducive to a noiseless gear drive, and the pinion should always be placed close to the motor bearing. A gear application with motor mounted upon the ceiling might be twice as noisy as the same application with motor mounted on a concrete foundation.

Pinions for High Torque Motors.—For series motors and those heavily compounded, as bending-roll motors, or for motors subject to very severe service of any kind, select a pinion suitable for a constant-speed motor of the same rated revolutions per minute, but of about 50 per cent. higher horse-power.

Selection of Ratio for Back-geared Motors.—A ratio of about 6 to 1 is usually standard for back-geared motors, and should be selected wherever possible, but smaller ratios down to 3 to 1 or maximum ratios up to 7 to 1 may be obtained in certain capacities of motors for service where the conditions of the application warrant the use of such ratios.

Outboard Bearings.—Outboard bearings should be used for geared motors of about 40 h.p. and above in heavy-geared service requiring continuous operation with frequent reversing and overloads; also for all motors of about 100 h.p. and above in any geared service. The proper use of outboard bearings cannot be emphasized too strongly, since on account of increased expense there is a tendency to omit them even where good engineering demands their use. It should be remembered that the best service is invariably the cheapest in the end.

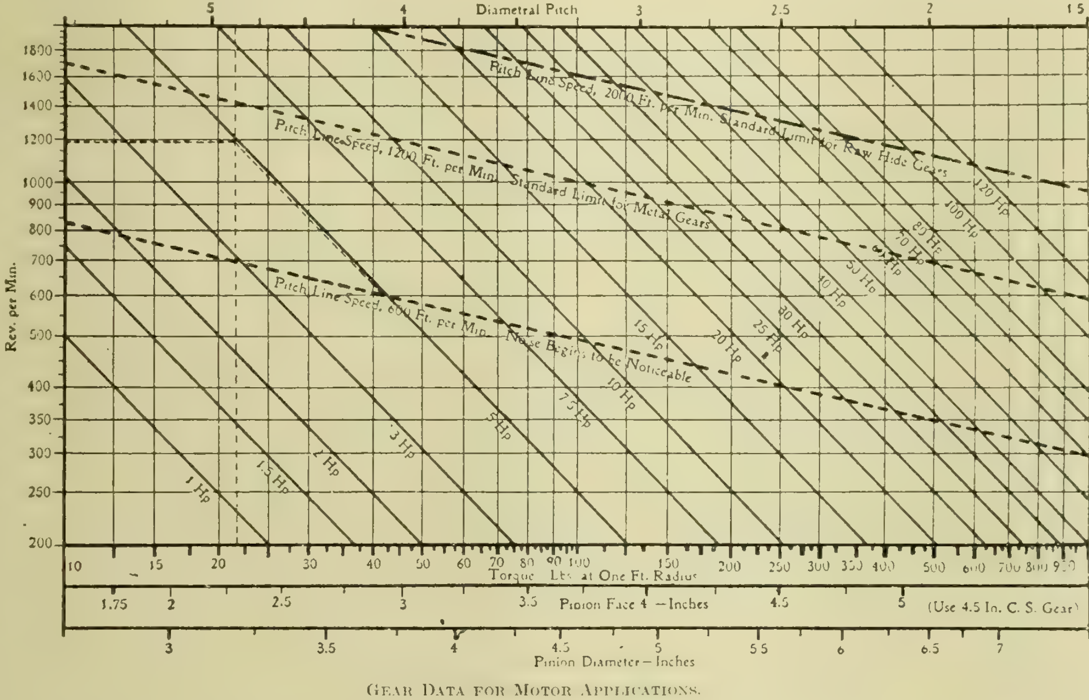
Definitions and Formulæ.—A circle whose circumference passes through the point of contact on each tooth of a gear or pinion when this point is on the line connecting the centres of the two wheels is called the *pitch circle*. The diameter of this circle is the *pitch diameter*, and its circumference is the *pitch line*.

Diameter, when applied to gears, is always understood to mean the pitch diameter.

Diametral Pitch is the number of teeth to each inch of the pitch diameter. To illustrate: If a pinion has 18 teeth and the pitch diameter is 3in., there are 6 teeth to each inch of the pitch diameter, and the diametral pitch is 6.

Circular Pitch is the distance from the centre of one tooth to the centre of the next, measured along the pitch line.

In the following formulæ, for use in gear problems, d^1 = pitch diameter of pinion; d = outside diameter of pinion; p = circular pitch; p^1 = diametral pitch; S = distance between centres = $\frac{1}{2}(D^1 + d^1)$; D^1 = pitch diameter of gear; D = outside diameter of gear; n = number of teeth on pinion; N = number of teeth on gear; r = gear ratio = $\frac{N}{n} = \frac{D^1}{d^1} = \frac{D}{d}$.



GEAR DATA FOR MOTOR APPLICATIONS.

$$p = \frac{\pi}{p^1} = \frac{\pi d}{n+2} \quad \text{. . . . . (1)}$$

$$p^1 = \frac{\pi}{p} = \frac{n+2}{d} \quad \text{. . . . . (2)}$$

$$n = d^1 p^1 = \frac{\pi d^1}{p} = d p^1 - 2 \quad \text{. . . . . (3)}$$

$$p^1 = \frac{n}{d^1} \quad \text{. . . . . (4)}$$

$$S = \frac{N+n}{2p^1} \quad \text{. . . . . (5)}$$

$$d^1 = \frac{2S}{r+1} \quad \text{. . . . . (6)}$$

$$D^1 = \frac{2Sr}{r+1} \quad \text{. . . . . (7)}$$

$$n = \frac{2Sp^1}{r+1} \quad \text{. . . . . (8)}$$

$$N = \frac{2Sp^1 r}{r+1} \quad \text{. . . . . (9)}$$

$$S = \frac{d^1(r+1)}{2} \quad \text{. . . . . (10)}$$

New Director of Naval Equipment.—Rear-Admiral Arthur W. Waymouth has been appointed to the new office of Director of Naval Equipment at the Admiralty.

NOTE ON THE GAS TURBINE.*

BY DUGALD CLERK, D.SC., F.R.S.

ENGINEERS engaged in the development of the internal-combustion engine have long recognised that great advantages would flow from the substitution of rotary for reciprocating movement, and accordingly many attempts have been made to produce a commercial gas turbine. So far, no attempt has succeeded; the practical difficulties have proved to be too serious. Much useful knowledge, however, has been obtained by able and adventurous experimenters, and we are now in a position to consider the difficulties afresh, with some experimental data at our disposal.

Most of the early experimental work upon any great and difficult problem must necessarily be of the forlorn-hope type, so far as concerns the attainment of commercial success. This is shown by the history of all great inventions. Pioneers in work of this kind should be highly honoured by engineers, and one of the names entitled to an honourable position is that of the late M. René Armengaud, who, together with M. Lemale, built in 1906 two experimental gas turbines of the constant-pressure type, one of which developed 30 b.h.p. and the other 300 b.h.p. A gas turbine of the explosion type, without compression, was built by M. Karovodine, in 1907. It gave 1·6 b.h.p. at 10,000 revs. per minute.

Recently the explosion type has been studied by Mr. Hans Holzwarth, who has built a gas turbine of a rated power of 1,000 h.p., the wheel of which rotates at 3,000 revs. per minute. Mr. Holzwarth has written an interesting book upon his work, in which he discusses the numerous scientific and practical points of the explosion type gas turbine in a very able and complete way.

In a paper written by M. René Armengaud, and published in "Cassier's Magazine," in January, 1907, the inventor gives an interesting account of his experimental work on the constant-pressure turbine. A small experimental machine, it appears, was made by altering a De Laval steam turbine of 25 h.p., so as to operate it with compressed air instead of steam. The air was supplied at the desired pressure from a high-speed compressor, whose efficiency had been carefully determined. The compressed air was passed into a combustion chamber with measured quantities of gasolene vapour, and the mixture was ignited as it entered the chamber by an incandescent platinum wire. The combustion was then maintained continuously at a constant pressure. The combustion chamber was lined with refractory material, ultimately carborundum, and a temperature of about 1,800° C. was maintained at the flame, but the mean temperature of the discharging gaseous contents of the chamber was reduced to 400° C. by the admixture of steam under pressure. This steam was generated in a coil embedded in a portion of the combustion chamber. The working fluid thus consisted of a mixture of products of combustion and steam at the low temperature of 400° C. The constant pressure maintained in the combustion chamber was about 10 atmospheres, and the hot gases were allowed to expand through a conical Laval jet in which the expansion produced a high velocity, and reduced the temperature of the fluid. At this reduced temperature and high velocity the gases impinged upon the Laval wheel, and rotated the wheel in the same way as steam would have done. The experiments showed that under these conditions the total power obtained from the turbine separate from the compressor was double that necessary to drive the compressor. In the large 300 h.p. turbine the first part of the combustion chamber was lined with carborundum, backed by sand, but the second part was surrounded by a coil through which water was circulated. The water kept the temperature of the combustion chamber within safe limits, and after absorbing heat, it passed also around the jet nozzle, and was discharged into the passage leading to the jet, and there converted into steam by the hot gases. A mixture of products of combustion and steam thus impinged upon the turbine wheel. The expanding jet was arranged to convert the whole of the energy into motion before the fluid struck the wheel; the temperature was thus reduced to a minimum before the gases touched the blades. Notwithstanding this, the wheel itself had passages through which cooling water flowed, and each blade was supplied with a hollow into which water found its way. In the large turbine the compressor was mounted on the turbine spindle; it was of the Rateau type, and consisted of an inverted turbine of four stages, which delivered the compressed air finally to the combustion chamber at a pressure of 112lbs. per square inch absolute. The efficiency of this turbine compressor was found to be about 65 per cent. The total efficiency of the combined turbine and compressor was low, as the fuel consumption amounted to nearly 3·9lbs. of petrol per brake-horse-power hour. This consumption was, of course, much too high to permit of the turbine having any chance as a commercial engine. An ordinary petrol engine with a moderate compression can readily give its power at the rate of 0·5lb. of petrol per brake-horse-power hour, and even assuming all practical difficulties overcome, so far as running was concerned, a consumption of six times that of the ordinary petrol engine for equal power was not sufficiently good for practice. The combined turbine and compressor was stated to have run at 4,000 revs. per minute, and to have developed 300 h.p. over and above the negative work absorbed by the compressor. Notwithstanding the high fuel consumption, it was a notable achievement to obtain 300 h.p. from an internal-combustion turbine under any circumstances, and had it not been for the untimely death of M. Armengaud this turbine might have been greatly advanced. So far as I know, however, the experiments upon the constant-pressure turbine have not been continued.

The explosion gas turbine invented by M. Karovodine was exceedingly ingenious. It contained four explosion chambers having four jets actuating a single turbine wheel, which wheel was of the Laval type, about 6in. diam., having a speed of 10,000 revs. per minute.

The explosion chambers were vertical, and had a water jacket surrounding the lower end. The upper portion contained the igniting plug on one side, and the discharge pipe connecting with the expanding jet on the other. In the lower water-jacketed part there was provided a circular cover, held in place by a screwed cap. This circular plate was perforated with many holes, and it carried a light steel plate valve of the flap or hinging type. This valve was pulled down by a spring contained within the admission passage. This spring could be adjusted, and the lift of the valve was regulated by means of a set screw passing diagonally through the water jacket. Air was admitted at one side by one pipe leading into the valve inlet chamber, and a corresponding passage or pipe admitted petrol and air or gas to mix with the air before reaching the thin plate valve. Adjusting contrivances were supplied in both air and fuel ducts. To start the apparatus, an air blast was forced through the valve, carrying with it sufficient petrol vapour to make the mixture explosive. The electrical igniter was started, and the spark kept passing continuously. Whenever the inflammable mixture reached the upper part of the combustion chamber ignition took place, and the pressure rose in the ordinary way, due to gaseous explosion. The gases were then discharged through the pipe and nozzle on to the Laval wheel. The cooling of the flame after explosion and the momentum of the moving gas column reduced the pressure within the explosion chamber to about 2lbs. per square inch below atmosphere. Air and petrol vapour then flowed in to fill up the chamber, and as soon as the mixture reached the igniter, explosion again occurred. In this way a series of explosions were automatically obtained, and a series of gaseous discharges were made upon the turbine wheel. Diagrams taken from the explosion chamber showed a fall in pressure during suction of 2lbs. per square inch; ignition occurred while the pressure was low, and the pressure rapidly rose to about $1\frac{1}{3}$ atmospheres absolute. The pressure propelling the gas column and jet was thus only 5lbs. per square inch above atmosphere. The pressure rapidly fell, and the whole process was repeated again. According to the diagrams taken, a complete oscillation required about 0·026 second, so that about 40 explosions per second were obtained.

Mr. Suplee, in his interesting work upon the gas turbine, describes experiments made by M. Baudezat on a turbine of this type. The volume of one chamber was 230 cubic cm. Each nozzle was 3 metres long and 16 mm. diam. The wheel itself was 150 mm. diam., or 5·9in. It made 10,000 revs. per minute, corresponding to a perimeter velocity of $78\frac{1}{2}$ metres, or 258ft. per second. At the time the diagrams were taken, the air drawn into the chamber was measured by a meter, and

* Paper read before section G of the British Association at Dundee, September 9th, 1912.

the petrol consumed was also measured. The brake power was determined by a Prony brake. The data and results obtained were as follows:—

Air consumed per hour ...	62·5 cubic metres = 80 kg.
Petrol	6·5 lits = 4·7 kg.
Length of brake arm	46·4 cm.
Weight on brake	248 grammes.
Speed	10,000 revs. per minute.

This experiment gave 1·6 b.h.p., and Mr. Suplee takes the wheel and journal friction as 0·5 h.p., so that the equivalent power was 2·1 i.h.p. The fuel consumption was nearly 6·5lbs. per brake-horse-power hour. The little explosion turbine thus consumed more than double the petrol required per horse-power as compared with the large constant-pressure turbine.

The large Holzwarth gas turbine also operates on the explosion principle, but the construction and action is very different from that of M. Karovodine. The turbine in general arrangement outwardly resembles the Curtis steam turbine, in that the turbine wheel rotates in a horizontal plane, the spindle or shaft is vertical and a dynamo is mounted on this spindle above the turbine. In the Holzwarth turbine 10 combustion chambers are provided, each of a pear or bag shape. They are arranged in a circle around the wheel, and are cast so as to form the base of the machine. The wheel is of the Curtis type, with two rows of moving and one row of stationary blades. Mr. Holzwarth does not give the dimensions of his turbine wheel, but from the drawings and some of the velocities given by him it appears to be about 1 metre in external diameter. The lower part of each combustion chamber carries gas and air inlet valves, and the upper part carries a nozzle arranged to cause the gases to impinge upon the first row of moving blades. This nozzle is connected to and disconnected from the combustion chamber by means of an ingeniously operated valve. The explosion chambers are charged with a mixture of gas and air, which appear to attain a pressure of about 2 atmospheres within the chamber before explosion. The air and gas are supplied under sufficient pressure from turbine compressors actuated by steam raised from the waste heat of the explosion and the gases of combustion, so that whatever work is done in compression is obtained by this regenerative action, and does not put any negative work upon the turbine itself. The combustion chambers are fired in series, by means of high-tension jump spark ignition. The action is as follows: Air is caused to flow through the combustion chamber to sweep out the products of the previous explosion, and also to assist in cooling the wheel by impinging upon it. The nozzle valve is closed, then gas is forced in to produce the explosive mixture. Gas and air valves are both closed, and the electric spark is passed. The pressure of the explosion opens the nozzle valve, and the gases acquire velocity within the nozzle, the temperature falls, and the high velocity lower temperature gases impinge upon the wheel. As the pressure falls, the nozzle valve gradually closes, but remains open until scavenging and cooling current has been passed through. When closed, the charging proceeds and explosions occur, as already described.

Many practical difficulties were found, but ultimately the turbine was operated by producer gas made from coke. It was found that when all 10 chambers were in operation the maximum pressure on explosion which could be obtained with the best mixture was only about 45lbs. above atmosphere. Using five combustion chambers, the best explosion pressure varied between 80lbs. and 90lbs. per square inch above atmosphere; while with four chambers, the highest result obtained was 105lbs. per square inch. So far as I understand Mr. Holzwarth's experiments, the highest power actually obtained was about 160 b.h.p. In this experiment 10 chambers were used, giving 16 h.p. each. With five chambers, a total of 145 h.p. was obtained, at 29 h.p. per chamber; and with four chambers, the total was 121·6 b.h.p. at 34 h.p. per chamber. With 10 chambers in operation the power fell to about one-half per chamber, as compared with four chambers. From these experiments Mr. Holzwarth came to the conclusion that the successive explosions interfered with each other, and prevented proper charging and action. Obviously with the arrangements used in the experiments, 10 chambers were inadmissible.

According to an interesting curve found at page 149 of Mr. Holzwarth's book, an explosion pressure of 105lbs. per square inch above atmosphere should have given in the turbine about 95 b.h.p. per chamber. With the 10 chambers in operation, this would justify the rated power of 1,000 h.p., but the actual power obtained per chamber even with only four chambers in operation was only about one-third of this. The weight of the turbine without the dynamo was 25½ tons, which, at the 1,000 h.p. rating, amounted to about 57lbs. per horse-power. The weight of the whole machine, with dynamo and economiser, with its steam-driven blowers, was 53½ tons, or 120lbs. per brake-horse-power total. These weights, after allowing for the necessary gas producers, do not improve upon ordinary reciprocating steam-engine weights, including boilers, even on the higher rating, but with the lower power actually found by the experiment, the weight per horse-power becomes impracticably large.

Mr. Holzwarth appears to claim a possible conversion of 30 per cent. of the heat supplied to the turbine into mechanical energy at the turbine shaft, and I understand that he has made this claim for the present turbine in its imperfect state. There is some mistake about this, because even on the air standard cycle, taking the approximate compressions used, and assuming expansion to atmosphere, the efficiency is too low to permit in practice in a reciprocating engine with its smaller heat losses more than about 15 per cent. With the larger turbine losses the theory of the Holzwarth machine does not appear to me to permit more than a 10 per cent. heat conversion, and so far as I understand Mr. Holzwarth's results, his actual conversion is much less than this.

Notwithstanding the unsatisfactory results of those experiments, Mr. Holzwarth is to be congratulated upon his courage and perseverance in attempting to solve a very difficult problem on so large a scale; and his work is not lost, because it supplies much-needed data which will enable either himself or other engineers to attack the problem afresh with better chances of success.

Undoubtedly the modern development of the steam turbine, displacing as it does so successfully all the larger reciprocating power units, and the difficulties of the large cylinder gas engine, apply an ever-increasing pressure to engineers desiring to use internal combustion for very large power units. The existing internal-combustion engines are quite satisfactory for small and moderate power units; but the weight increases so rapidly with increase of cylinder diameter that large units such as 20,000 h.p. per shaft, easily attained by the turbine, have proved quite impossible for the reciprocating gas engine. In order to apply internal-combustion for the purpose of such large units, it appears to me to be necessary to dispense with the cylinder piston and crank. I fear that this cannot be done on the lines of either constant-pressure or explosion turbines here shortly discussed. Difficulties which I pointed out to the Junior Institution of Engineers in 1905 still remain; and notwithstanding the great ability from both the scientific and practical points of view of the inventors who have experimented with the subject, the results obtained only appear to show that progress can hardly be expected on the lines of flame impinging on turbine blades, either in impulse or reaction turbines. Several engineers have suggested the use of explosion to give water velocity, which velocity actuates a water turbine of some form. Mr. Humphrey, in his paper to the Institution of Mechanical Engineers, figures such a combined gas and water turbine; and although in the form suggested by him the conditions required too cumbrous a machine, yet it does seem to me that the more hopeful line is to use explosion and expansion to give water velocity, and so avoid all heat difficulties in the turbine part of the apparatus. It is true that such an arrangement still necessitates a reciprocating mass of water, but it will probably be found that great gain in weight can be obtained by the suppression of the piston, connecting rod, engine frame, and crank. This line seems to me to be a much more hopeful one than any scheme involving the direct contact of flame with turbine blades.

The Lock-out of Glasgow Tube Workers.—A communication was received at Glasgow on Tuesday last from the Board of Trade stating that that department would immediately enquire into the circumstances attending the lock-out of 2,000 tube workers at Messrs. Stewart & Lloyds' Phœnix Works.

THE WORK OF THE TESTING ENGINEER.*

BY HENRY M. HOWE.

OUR purpose is to serve humanity by enabling it to distinguish the fit from the unfit among the materials with which the world's work is done—the materials for its buildings, its bridges, its ships, its railroads, its machinery, and its constructions in general. This is the function of the testing engineer. He stands between the public and the manufacturer who would supply that public to test the fitness of those supplies, to measure accurately their degree of fitness, and to reject unsparingly the unfit. He is a guardian of the lives of those who travel by land or sea, and of those who live or work in buildings of important size. He is a protector of the material interests of the public, because in the last analysis all structures and all materials of which they are made are for the use and benefit of the public individually or collectively, and are paid for directly or indirectly by that public; and it is to the interest of that public that the fitness of those materials for their various purposes shall be known quantitatively to those who select them.

It is to make this work of the testing engineer more effective, to guard the lives and the interests of the public the better, that this association exists. It is an open court in which the public sits in judgment on the various methods of testing. Of that public certain parts are here represented directly by their own engineers. This is true of the great railroads, the great shipbuilders and bridge builders, and the great engineering houses. Other parts of the public are represented indirectly by the middlemen or by the public engineers of tests.

The results of experience in all lands, in all climates, and under all conditions, and the points of view of all races, are here focussed in the most searching criticism of the various methods of testing, to the end that the buyer may gauge their fitness with full knowledge, and thus may select intelligently those which give the fullest protection first to himself and ultimately to the public. If one method is unduly favourable to one manufacturer or to the manufacturers of one region or of one country by tending to gloss over the shortcomings of their product and to give undue prominence to its special merits, the public is here warned of the deceptiveness of that test by the evidence offered by the competing manufacturers.

However far distant may be the political "Parliament of Man," which is "coming yet for a' that," the industrial parliament of man is already here. The buyer in each country may well say, "My country is the world, my countrymen are all mankind," for wherever his abode he selects the fittest goods, quality and cost considered, without regard to their origin. While he is selecting his purchases, friendship, patriotism, national boundaries, empires, and continents cease to exist. To-day's market place is the world, and our society is an essential part of that pentecostal market place, in which we enable all races to speak the common language of the methods of testing, that is, of appraising the market place's competing goods.

An important phase of our work is the unification of the methods of testing throughout the world, to the end that the buyer may the more readily and the more justly weigh the relative merits of all competing materials of a given kind, from whatever country they may come. The day has passed when the buyer's ignorance, his inability to ascertain for himself the fitness of what is offered him, forced him to rely on the reputation and on the assurances of the manufacturer or exporter. To-day he relies not on the untested assertions of the seller, however credible, but on his own tests, or on tests made by his own agents. Purchase is no longer a matter of faith but one of knowledge. It is our mission and privilege to carry this substitution of knowledge for faith ever farther and farther.

Turning our attention now in a different direction and asking what our attitude ought to be toward attempts to replace or supplement our present methods of testing with new methods, we find that, though we have good reason to be dissatisfied with our present methods, yet we should be extremely cautious in the industrial adoption of new ones. Let us consider these two aspects briefly.

* Abstract of presidential address delivered before the New York Congress of the International Association for Testing Materials.

For every structure there are certain conditions which are more trying to it than all other conditions, certain conditions which it fulfils with the greatest difficulty. Its ability to meet these most trying conditions is the measure of its industrial and commercial fitness, usefulness, and hence value. The fact that I cannot lay my hand with certainty on these conditions does not affect the truth of this proposition. We may not know these conditions to-day, but they are intrinsically discoverable. The supreme danger to the chimney may be the gale. The supreme danger to the rail may be the unduly rapid impact of an ill-balanced driving wheel when the ground is frozen hard, and after the head of the rail itself has been brought from its initial ductility to the vitreous state by the peening of the wheels. The supreme danger to the hull plate may be the dynamic stress along the rivet holes in a collision. That which at last breaks down the well-aligned factory shaft may be the inevitable slight variations of stress. In each case there are probably two or more supremely trying sets of conditions; but be they few or be they many, be they recognised or be they still undiscovered, there must in the nature of the case be such most trying conditions, the ability to endure which necessarily carries along with it the ability to endure all of the other conditions of use. It is to these most trying conditions that our tests should address themselves.

We assume reasonably that the ability to meet these most trying conditions will be measured most trustworthily by that test which reproduces these same conditions the most closely. For instance in the many cases in which the most trying stresses are dynamic, it is reasonable to believe that a dynamic test is fitter than a static one. Of course we should not leap to the conclusion that any and every dynamic test is here fitter than any and every static test.

Here, then, is one direction in which most of our tests are very faulty. Their conditions are radically unlike the most trying ones of service. The light which they throw on the fitness of the object for its proposed service is most indirect. In that respect they are unfit tests.

An objection from a wholly different direction lies against most of our tests: the objection that, because they are tests to destruction, they cannot in their nature be applied directly to the object whose fitness they would gauge, but instead they must be applied vicariously to small pieces assumed to represent those objects. We do not test the individual rails, boiler plates, shafts, bridge posts, or concrete columns on whose fitness the lives of our fellows hang, but small pieces cut from them, or for some other reason assumed to represent them. In certain rare cases we do indeed test, not such a small fragment, but a similar whole structure, a like beam or shaft or post. This is not as bad as measuring the endurance of your recruits by finding what forced march suffices to kill their brothers, but it is open to the same kind of objection, the objection that because it is destructive it must needs be vicarious.

But a great range and variety of indestructive tests suggest themselves, tests which leave no more effect on the piece tested than seeing, tasting, or smelling it would. The presence of cavities may be detected through the density, and that of plastic deformation through the potential. Microscopic examination is already well advanced. Magnetic testing has received much attention; and electrical disintegration is now pointed out as a means of test. The number of physical properties which offer themselves as possible means of testing is very great.

Here we note that Miers and Isaac determine the supersolubility curve of solutions by measuring their index of refraction of light, and that Hönigsberg and Coker study the lines of stress by the behaviour of polarised light passed through transparent specimens. What do these things mean? They mean that light, a manifestation of energy, in crossing these bodies undergoes a change; and the nature of that change teaches us concerning properties in those crossed bodies little related to light; or, in short, the action of the body tested upon a form of energy passed through it or reflected from it may be made to disclose and to gauge properties of that body but little related to that form of energy and with no residual effect on the body itself.

But light is only one of a considerable number of forms of energy which seem open to such use. Sound, electricity, the divers kinds of radiations which only lately disclose themselves to our amazement, and the many yet undreamed ones awaiting

discovery; these are forms of energy some of which may be harnessable to a like use.

Let us remember that later our analysis of these subtler manifestations of energy will be even fuller than our present analysis of the coarse radiations of sound. As to-day we know not only the pitch and volume, but the timbre, overtones and harmonics of sound, so later shall we know corresponding characteristics and phenomena of these other kinds of radiation, so that we seem embarrassed by the riches of the variety of agencies from which the testing engineer of an age less crude than ours may choose.

Here lies the suggestion that we may learn the properties of the very rails and girders which we are to use, and later the properties of assembled structures themselves, such as boilers and bridge posts, and conceivably in the far, far future the assembled hull, by their action and reaction with some form of energy. Who shall say that the pitch or volume or timbre of sound emitted by a rail as the result of a given excitement may not be made to disclose pitilessly its hidden defects and to measure the fitness, not alone of the material of which it is composed, but of the rail as a whole structure? Or, giving rein to our fancy, we hear the inspector report, "This one-hundred-storey building indeed responds to G sharp, but its timbre has this abnormality and these harmonics are exaggerated."

These indestructive methods indeed have the defect of being indirect in one respect, to weigh against their advantage of being direct in another; they are indirect in that they gauge the properties actually needed in service by means of other properties; they are direct in that they may be applied to the very objects to be used, instead of vicariously to coupons or like objects to be destroyed in the test itself.

Their natural service seems to supplement the vicarious destructive tests. Thus the tester of the future may prove his material by the vicarious destructive tests of coupons, and prove his structures themselves by these indestructive tests.

It is not to imply that such means are of our decade or even of our century that I have hinted at them, but rather that we may put ourselves in the right attitude towards our art. It is well to climb at intervals from our details to the top of some lofty pyramid, and, looking afar, see how the brightness of the future contrasts with the darkness of our present unfathomable ignorance.

That our present state seems to us modern is nothing; every period in the last 15 centuries has seemed modern to itself. If, remembering the wonderful progress, scientific, industrial, and social, in our time we admit that progress is accelerating; if from Fielding's photograph of life we infer that the progress in the 160 odd years since it was written has been as great as in the 1,600 odd years which preceded it, and hence that the acceleration itself is rapid; if we then admit both that the acceleration will continue, and that man will continue to dominate the earth not for centuries but for millions of years; that the middle ages are not behind but far before us and we ourselves at the dawn of history; if we do this, we may gain some idea of the futility of imagining that we in this stream of progress ought to lie at anchor: and we may recognise that the methods which our present ignorance and crudeness have evolved are mere temporary makeshifts.

Let us remember that till very lately our most competent authorities have been unable to answer the elementary and readily answerable question, "Does a soft or a hard rail better resist abrasion?" The facts that such relatively modern marvels as the reciprocating engine and the Bessemer process seem already threatened and that the electric telegraph has already yielded much of its importance to the telephone and to radio-telegraphy, may help us to a right attitude, in which we concede that as to-day's makeshift testing methods are sure to be displaced some day by some new ones, the new ones offered to-day may be those which are to displace them.

On the other hand, the frictional resistance to the introduction of any new method of testing is so great, and the kind of mental and moral energy needed for overcoming this resistance is so limited in quantity and so precious to mankind, that we reasonably require the advocates of new methods to elaborate them, to put them into serviceable condition, and to provide convincing proof both that they are competent and that the form in which they are offered is reasonable and fit. Till then we can hardly be expected to urge their industrial adoption even as supplementary tests; and of course we cannot consider substituting them for existing tests till their competence and their advantages have been overwhelmingly demonstrated, so momentous are the interests at stake. Though we recognise the need of progress, we recognise also the need of scrutinising most searchingly every contemplated step of that progress.

The immediate purpose before the founders of our society was to perfect and unify the methods of testing; the ultimate purpose was to enable the public to get fit goods. But if I am to learn whether my purchase is fit by testing it, I must know not only how to test it, *i.e.*, how to measure its properties, but also how much of each property it ought to have. Of what use is a process for testing axles by impact or tension unless I know quantitatively what tensile properties they ought to have and what impact they ought to endure? Of what use are methods of testing without reception specifications? One is the necessary complement of the other.

It so happens that, in building a society fitted for the immediate end of improving methods of testing, we have simultaneously fitted it for the indispensable supplement, specification making. In bringing together those competent to improve methods of test we have also brought together those most competent to draw specifications. We have "builded better than we knew." We have unconsciously made an organisation fitted for filling both needs of the public, for telling it both what properties, quantitatively, its purchases need and also how to measure those properties.

I am not unmindful of the obstacles and pitfalls in the way of specification making. I understand the gravity of the commercial questions involved. I see that commercial interests may readily be antagonised into the position of resenting supposed interference. But let us look at obstacles as things primarily to be overcome and pitfalls as things primarily to be bridged, remembering that where there is a will there is a way; that the human beings with commercial interests on other continents do not differ in their innermost nature from the corresponding human beings on this continent; and that if it has proved possible to bring maker and user into harmonious and indeed enthusiastic co-operation here it ought to be possible there.

The natural development of the American Society for Testing Materials has happened to be in the direction of specification making. In our opinion, based on our now very considerable experience, this work has proved far more valuable, and of far greater profit to the public, than our simultaneous work of perfecting methods of measurement.

I have sought to impress on you that we are among the guardians of mankind; that our services to humanity are of so high a nature as to stimulate us to seek earnestly how we may make them more effective and wider; that one means is to supplement and in time replace our present methods, which rightly viewed are but temporary expedients, with better ones; but that this replacement, much as it is needed, should be made with extreme caution. Classing the methods of testing into the vicarious tests to destruction on one hand and on the other hand the indestructive tests applied directly to the objects which are to enter into service, I have pointed out that in the future these two classes of tests may well be used to supplement each other; that the vicarious tests should be made to reproduce as closely as possible the most trying conditions of service, and that the indestructive tests, with which we have hardly made even a beginning, hold out very wide possibilities of usefulness. I have urged on you our competence and our consequent duty to add specification-making to our original plan, and thereby to increase very greatly our services to our brothers, and through our brothers to our Father. Here are tasks which may well fire our imagination and stimulate us to an ardent consecration of our energies to the work of the International Association for Testing Materials.

The Municipal Tramways Association.—The 11th annual conference of the Municipal Tramways Association will be held at West Ham from September 25th to 27th. The presidential address will be delivered by Mr. H. E. Blain, of West Ham. Papers will be delivered by Mr. S. C. T. Neumann on "Tramways Administration by Municipalities: A Retrospect and a Forecast," and by Mr. W. J. McCombe on "Tramway Fares and Their Basis." A discussion on the interim report of the Corrugation Committee will be opened by Mr. C. A. King.

INDUSTRIAL AND TRADE NOTES.

Indian Railways.—The report on the railways in India for the year 1911, just issued, states that during the year there were 755 miles of line opened to traffic, bringing the total mileage open up to 32,839.

Oil Tank Steamers.—The boom in the oil trade has resulted in an unprecedented demand for tank steamers, of which another was launched on the 13th inst. from the yard of Messrs. Swan, Hunter, & Wigham Richardson, Ltd., Wallsend.

Engineers' Wages Advanced. — The Executive Council of the Amalgamated Society of Engineers announce a wages advance of 1s. and 2½ per cent. on piece rates at Leeds, Ashton, Hyde, and Dukinfield, and a general advance of 2s. at Doncaster and Chesterfield.

A Large Turning Lathe.—The firm of Thomas Shanks & Co. Union Ironworks, Johnstone, have just completed a large turning lathe, weighing 270 tons, for the firm of John Brown & Sons, Sheffield. It is specially designed to deal with large ingots which will be used for the motors of the turbines of battle-ships, and is being sent from Johnstone in parts. The lathe is the biggest and heaviest of its type.

German Pig-iron Production. — The production of pig iron in Germany during August reached the record figure of 1,487,447 metric tons, compared with 1,285,942 metric tons for the corresponding month of 1911. The total production of pig iron in Germany for the eight months ending August 31st amounted to 11,380,091 metric tons against 10,258,687 metric tons for the corresponding period of 1911.

Shipbuilding Orders. — The P. and O. Company have placed orders for four new steamers—two with Messrs. Cammell, Laird, and Co., and two with Messrs. Caird & Co., each of 9,000 tons register. These ships are designed chiefly for the Indian trade, and while they will possess a large amount of cargo space, they will have accommodation for about 150 passengers in the first and second saloons.

Clyde Oil Engine Factory.—Lord Pirrie, in conjunction with the Danish shipbuilding firm of Burmeister & Wain, is, we understand, forming a company to manufacture Diesel marine oil engines on the Clyde. Lord Pirrie has been closely watching developments in this matter, and recently visited Copenhagen with a Queen's Island expert. During the trials of the "Zelandia" it became known that Messrs. Workman & Clark, of Belfast, as well as Harland & Wolff, have been experimenting for some time as to the utility of oil engines in large liners.

Proposed Eight-hours Day in the Iron and Steel Trades.—At the conference of the International Association for Labour Legislation, which has just concluded its sittings at Zurich, the possibility of introducing the eight-hour shift in continuous industries was discussed, and it was decided that this question was ripe for action as far as the iron and steel trade is concerned. As a result the association will now proceed to approach the Governments of the various countries concerned with a view to getting the three-shift system introduced in iron and steel works by means of an international agreement.

Pit Sinking Record.—A pit sinking record has been established in connection with the Doncaster coalfield. On Saturday morning last the sinkers employed at the new colliery being sunk at Askern Spa, near Doncaster, by the Askern Spa Coal and Iron Company, reached the coal seam at a depth of 565 yards. In No. 1 shaft the seam is 9ft. thick and of excellent quality. Sinking was only commenced in the December of 1911, so that the progress made has been remarkably rapid, the average having been 14 yards per week. Seventy-six yards of tubbing had to be placed in each shaft to dam out 4,000 gallons of water per minute.

The Trade of Norway.—According to a British Consular report, the year 1911 was particularly favourable to the trade and industry of Norway. Of the total amount of coal, about 2,187,000 tons, imported into Norway in 1911, about 1,969,857 tons came from the United Kingdom. Apart from labour conflicts in the cellulose and other trades, unemployment was less in 1911 than in 1910, and was unusually small. The attention of British firms is especially invited to the industrial developments which appear likely in Norway in the near future, especially in connection with the mining, electric, smelting and dependent industries, and in the general development of water power for industrial purposes.

Railway and Tramway Returns.—Some interesting figures relating to railways and tramways are contained in a Government return issued on Monday last. The figures disclose that the paid up capital of railways was in 1911: England and Wales, £148,519,000; Scotland, £49,348,000; Ireland, £216,000; a total for the United Kingdom of £198,083,000. The mileage of the railways of the United Kingdom in 1911 was 23,417. The net receipts last year were £48,581,746, and the proportion of working expenses to gross receipts was 62 per cent. In 1911 there were 25,997 miles of tramways and light railways in the United Kingdom, with a capital of £72,725,440. The passengers carried numbered 2,907,177,120, and the net receipts were £5,276,060.

Shipyard Agreement. — A conference of considerable importance to boilermakers throughout the North of England and the Clyde was held in Newcastle on the question of the National shipyard agreement, so far as it affects the Boilermakers' Society. This society, along with other signatories to the agreement, recently gave notice for it to terminate. At the conclusion of the conference Mr. John Hill, general secretary, stated that there was nothing to communicate. There was a feeling among some of the delegates, it was afterwards learned, that it would be advisable to take another ballot of members on the question of the desirability or otherwise of an amended agreement. The last ballot was not a strong one, fewer than 5,000 members having voted on any of the four given questions, whereas the total membership of the union at the time was over 50,000.

Trade Openings on Completion of Panama Canal.—The Board of Trade has received information to the effect that certain foreign manufacturers are carrying out an organised campaign in South America, especially in those countries which will be brought into closer contact with the principal manufacturing countries by the opening of the Panama Canal, viz., Bolivia, Peru, Ecuador, and Colombia, with a view to capturing the local markets at the earliest possible opportunity. As an instance, it is said that one important firm of continental manufacturers have dispatched a commissioner on their own account to investigate and report to them in detail on the prospects and development of the countries named, and the probable requirements of settlers and natives, so that they may be able to make arrangements for securing the market for their goods. Foreign companies, interested in the metallurgical possibilities of the countries referred to, are also said to have a number of men already on the spot with the object of securing the most promising mining claims in anticipation of the time when the shipment of ores may become commercially practicable.

Revival of Trade Activity in Spain. — The American Consul-General at Barcelona, in a report to Washington, states that while Spain's actual commercial progress from year to year has not been great, trade activity is now evident, and a general revival is noticeable. The establishment of land banks in important agricultural centres, and the industrial legislation which is being put forward, are important factors. Great Britain and France lead in the competition for this trade, followed by Germany and the United States with much smaller totals. The large purchases of machinery indicate the industrial expansion which is now going on. Agriculture is the principal industry of Spain. The primitive tools formerly in use are being replaced by modern appliances, and the area of land under irrigation is increasing. The Consul states that statistics show Spain's coalfields to extend over an area of 4,117 square miles, more than half of this area being in the northern part of the country. There are 601 productive mines, with a surface area of 60,337 acres, and 3,529 unproductive mines with an area of 424,553 acres. Notwithstanding this great coal wealth the annual production does not exceed 4,000,000 tons. The lack of transportation facilities is the principal factor which impedes the development of Spain's coal industry.

Employment in August.—The Labour Department of the Board of Trade report that employment during August continued good, and was an improvement on the previous month. It was considerably better than a year ago. The percentage of trade union members unemployed, so far as reported in the Department, was the lowest recorded since July, 1900. Compared with a month ago, there was an improvement in the coal mining, iron and steel, engineering, and shipbuilding trades. Nearly all industries showed a marked improvement. Employment in the month was, however, adversely affected by the disputes in the railway and other transport trades. In the 383 trade unions, with a net membership of 872,817, making returns, 19,556 (or 2·2 per cent.) were returned as unemployed at the end of August, compared with 2·6 per cent. at the end of July and 3·3 per cent. at the end of August last year. The changes in rates of wages taking effect in August were all increases, and amounted to £6,300 per week on the wages of 150,000 workpeople. The number of disputes beginning in August was 48, and the total number of work people involved in all disputes in progress during the month was 54,961, as compared with 117,333 in July and 373,615 in August, 1911.

Proposed Bridge to Span the Mersey.—A revival of the idea of building a bridge over the Mersey at Liverpool is arousing con-

siderable public interest. At the present time, apart from the tunnel railway, the traffic, both passenger and goods, is carried by ferries, and it is held that in contrast with the engineering enterprises carried out elsewhere, these are out of date, as well as inadequate. In an article in the "Liverpool Express" particulars are given of a scheme designed by prominent experts, including Mr. John A. Brodie, the present city engineer, which found much favour with the local public men at the time it was put forward. The bridge then proposed was a suspension, which was believed to be the most economical, would obstruct the river traffic less, and be much more graceful in appearance than any other type. It was proposed to cross the river in three spans, a central one of 2,000ft., and two side spans of 1,000ft. each. The bridge would be nearly two miles long, and by gradient reach a height in the centre of the river of 150ft. There was also to be approaches for heavy traffic, while auxiliary hydraulic lifts would be provided near the dock on either side of the river. The total necessary capital for the completion of the scheme was estimated at £2,714,750, and the bridge was to take five years to build.

Trade of British South Africa.—A White Paper just issued contains the report on the trade of British South Africa during the year 1911, by Sir R. Sothern Holland, H.M. Trade Commissioner. According to this the total exports of South African produce amounted in 1907 to £47,595,665. Last year the exports reached a total of £57,734,875, an increase for the quinquennial period of £10,139,210, or 21·3 per cent. The total imports of general merchandise amounted in 1907 to £25,897,161, in 1911 to £36,423,539, or an increase within five years of 10½ million pounds, or 40·65 per cent. Out of the total import trade for the year 1911 of £36,400,000, the United Kingdom supplied £21,250,000, or 58·35 per cent., while the trade of the British Empire as a whole amounted to £24,900,000, or 68·4 per cent. Against this the trade of foreign countries taken together amounted to £11,500,000, or 31·6 per cent. Sir R. Sothern Holland has arrived in this country, and intends visiting the principal industrial centres of the United Kingdom, and giving to British manufacturers and merchants an opportunity of consulting him with regard to trade conditions and openings in South Africa. Before proceeding to visit the Chambers of Commerce he may be seen by appointment daily at the Commercial Intelligence Branch of the Board of Trade, 73, Basinghall Street, London, E.C., from September 23rd to October 4th, and British manufacturers and merchants who may desire an interview with him are requested to apply to the Director of the Branch, as soon as possible, for an appointment.

Australian Trade.—A report on the trade of the Commonwealth of Australia during the year 1911 by Mr. C. Hamilton Wickes, H.M. Trade Commissioner, just issued, states that the year 1911 was a prosperous one for the Commonwealth of Australia. Manufacturers were fully occupied, although there was some restlessness among employés, culminating in strikes in certain districts. The imports and exports show a considerable increase over the previous year, and the gross totals for a record. During the past year, the report states, foreign firms, particularly American, have been paying increased attention to Australia, by sending over special representatives to organise their agency arrangements in the various States, and by improving their selling organisation in other ways. The report continues: "The unsatisfactory position of the British manufacturer as a supplier of agricultural implements and machinery is patent. The opinion generally expressed in Australia regarding the comparatively small trade done by the United Kingdom is that the British manufacturer does not supply according to the requirements of the market. Whatever truth there may be in this criticism, it is certainly true that such British manufacturers as are represented in Australia, either by their own office or otherwise, in this class of goods appear in selling to follow the line of least resistance, and to neglect the pushing of their agricultural implements. Particularly is this the case as regards goods in general use, in which there is necessarily considerable competition from the local and North American manufacturers."

Shipyards and the Factory and Workshop Act, 1901.—The following Order of the Secretary of State, dated August 23rd, 1912, has been issued: Section 116 shall be modified so as to read as follows: (1) The occupier or contractor shall, for the purpose of enabling each worker who is paid by the piece to compute the total amount of wages payable to him in respect of his work, cause to be published particulars of the work and rate of wages applicable thereto, as follows: *(a)* He shall furnish every worker with written particulars of the rate of wages applicable to the work done by him at or before the time of his first employment on the work and on every subsequent occasion when the rates are fixed or altered; or he shall exhibit such particulars on a placard in the factory or workshop. Provided that if the rates are not ascertainable before the work is given out, the particulars shall be furnished to the worker in writing when the work is completed. *(b)* Such particulars of the work done as affect the amount of wages payable to each worker shall be furnished to him in writing when the work is completed. (2) Where the work is done in common by a gang of workers it shall be sufficient if the particulars of the work done by the gang and of the rate of wages applicable thereto are furnished to the member of the gang to whom the wages of the gang are paid by the employer. (3) The particulars, either as to rate of wages or as to work, shall not be expressed by means of symbols. (4) Any placard exhibited in pursuance of the foregoing provisions shall contain no other matter than particulars of rates of wages, and shall be affixed in such a position as to be easily read by all persons to whose work the particulars relate. (5) If the occupier or contractor fails to comply with the requirements of this section, he shall be liable for each offence to a fine of not more than £10, and, in the case of a second or subsequent conviction within two years from the last conviction for that offence, not less than £1. (6) If anyone engaged as a worker in the aforesaid class of work, having received such particulars, whether they are furnished directly to him or to a fellow-workman, discloses the particulars for the purpose of divulging a trade secret, he shall be liable to a fine not exceeding £10. (7) If anyone for the purpose of obtaining knowledge of or divulging a trade secret, solicits or procures a person so engaged to disclose such particulars, or with that object pays or rewards any such person, or causes any person to be paid or rewarded for so disclosing such particulars, he shall be liable to a fine not exceeding £10. (8) The Order of December 30th, 1909, relating to shipbuilding yards, so far as concerns the work of platers, riveters, and caulkers, is hereby repealed. This Order shall come into force on October 1st, 1912.

The Manchester Rails Contract.—An interesting communication by Mr. J. H. Longford, formerly H.M. Consul at Nagasaki, with reference to this contract, appeared in a recent issue of the "Morning Post." He states: "There is a great deal more involved in the preference given to an American firm by the Manchester City Council in the contract for steel rails than the immediate loss of over £10,000 to British industry. The incident will be freely and very properly used as an advertisement not only by the individual firm directly interested in it, but by others engaged in similar industries, certainly in China and Japan, and no doubt also throughout the Latin States of South America, it may be even in our own Australian and Cape Colonies. Pamphlets will be drawn up in the Chinese and Japanese vernacular languages and freely circulated by active agents on the spot among all buyers, in which the transaction will be fully described and emphasis laid on the statements in the debate in the Council that the American product is fully equal in quality to that of the best Sheffield firms, and is at the same time both substantially cheaper and more quickly delivered. Speedy delivery is of the essence of all contracts for public works, and if an American firm in Pennsylvania can deliver goods in Manchester more speedily than an English firm in Sheffield, how much greater will be the advantage of dealing with the former when the delivery has to be made either in the Far East or in South America! These points will be urged by agents who are, as a rule, not at all scrupulous in using unfair arguments, and will make the most of these which are perfectly honourable and are provided by ourselves. The ultimate results may be not a loss of £10,000, but of many tens, even hundreds, of thousands of pounds and a permanent injury to British industry." As an instance of the use of this method of advertisement, he refers to the contract for the Atbara bridge in Egypt, which was given by the India Office to an American firm in the late nineties of the last century. "This contract," he continues, "was then defended in the House of Commons in similar terms to those that have just been used in the Manchester City Council. Every word of the defence was fully translated into Japanese and Chinese and widely circulated, both in pamphlets and in advertisements and articles in the native Press, and no expense was spared by American agents in securing the widest publicity to the fact that the superior efficiency of American to British steel foundries was admitted in the most convincing way in England. I pointed this out, as fully and as strongly as was compatible with official limits, in my annual trade report for the year, but the report was edited in the Foreign Office, and all I wrote on this point was struck out before publication."

Proposed New Railway in the Lothians.—The North British Railway Company is to approach Parliament for powers to construct a new railway in the Lothians to provide for the development of the coal traffic. The principal line will run from Leith Docks to Monktonhall.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 58, New Bailey Street, Manchester.

MECHANICAL, 1911.

Sparking regulator for internal combustion engines. Hutchinson. 8206.
Evaporation, distillation, and similar operations. Söderland and Testrup. 12462.
Supplying of water to the vaporisers of internal combustion engines. Neumann. 12467.
Air ships. Dodman. 12756.
Locomotive boiler furnaces. Gregory, Gregory, and Direct Gas Fuel, Ltd. 12900.
Valves. Barlow & Lord. 16013.
Valve gear for internal combustion motors. Dupuis. 16953.
Water-purification plants. York. 17215.
Steam-generator gauge. Fletcher & Green. 17317.
Separation of ores. Murex Magnetic Company, Ltd., & Lockwood. 18189.
Apparatus for burning liquid fuel. Kermode. 19058.
Separation of metals from zinc bearing ores or compounds. Ashcroft. 19257.
Retainers for ball bearings. Aktiebolaget Svenska Kullager-Fabriken. 19324.
Power hammers or forging apparatus for use in chain making. Lelong. 19326.
Locomotive engines. Garratt. 19338.
Wrenches. Willis. 19514.
Steam regenerative accumulators and water heaters. Morison. 19564.
Cone friction clutches. Daimler Motoren Ges. 19585.
Flying machines and air ships. Stoddart. 19664.
Carburetters for internal combustion engines. Ware. 19722.
Steam generators. Willis. 19915.
Steam generators. Solomiac & Olier. 20035.
Couplings for haulage wagons. Atkins & Adams. 20281.
Tool for assisting in the removal of the valves of internal combustion engines. Terry. 20337.
Oil sprayers for internal-combustion engines. Crossley, Webb, and Barley. 20758.
Internal combustion engines. Wolseley Tool and Motor car Company and Remington. 20959.
Wrench. Wright. 21384.
Governing mechanism for elastic fluid turbines. Warwick Machinery Company (1908). 21918.
Propulsion of vessels. Yarrow. 21977.
Condensers for steam engines. Eastwood. 22005.
Device for indicating an abrupt change of temperature. Burn. 22084.
Construction and propelling of canal boats. Harding. 22139.
Variable-speed gearing. Saver Clutch Company, Drake, and Hewitt. 22650.
Nut locks. Smith. 22823.
Clutches. Miles. 22825.
Lubricating the axles of colliery tubs. Medd. 23434.
Positive safety device for lift and hoist openings. Medway. 23449.
Appliances for miners' lamps. Mercer. 25371.
Combustion chambers of internal-combustion engines. Weller. 26270.
Heat exchange devices. Lomschakow. 26340.
Change speed gear and motor control in motor vehicles. Stratton and Perrett. 27293.
Ratchet driven pump for petrol engines. Southard. 27301.
Radiators for heating buildings. Alldays & Onions Pneumatic Engineering Company and Stott. 29166.
Worm gearing. David Brown & Sons (Huddersfield), Ltd., and Moore. 29247.

1912.

Screw operated hydraulic power appliances. Adams & Windsor. 1310.
Steam engines of the rotary type. Girod. 2340.
Speed indicating apparatus. Vidal. 2361.
Condensers for zinc vapours. Queneau. 2669.
Railways with a single guiding rail. Enock. 2807.
Conveying heating gas to coke ovens. Collin. 2965.
Elevated and suspension railways. Adolf Bleichert & Co. 4180.
Apparatus for annealing metallic articles. Kreidler. 4188.
Centrifugal air or gas pumps. Massip. 4305.
Screw nuts. Pius and Feilchenfeld. 4741.
Construction of railway and tramway tracks. Ramy. 5583.
Dirigible air ships. De Lan. 5819.
Liquid transmission of power apparatus. Zambon. 6787.
Grinding or reducing apparatus. Barthelmess. 7270.
Variable-speed friction gearing. Forest. 7569.
Flying machines. Eggert. 7886.
Rotary air and gas compressors. Milne. 8658.
Methods of grinding balls. Greene. 8662 and 8663.
Grease injectors or lubricators. Morris. 9000.
Centrifugal ejector pumps. Watson & Billetop. 9054.
Aeroplanes. Bancroft. 9547.
Grinding machines. Churchill Machine Tool Company, March, and Asbridge. 11124.
Instruments for centring purposes. Eisner. 11267.
Automatic loading apparatus for use on aerial railways. Dumont. 11548.
Ships. Clift. 11858.
Combined reciprocating engines and turbine plants. Schmidt. 12698.
Propellers for aeroplanes. Reuter. 13608.
Aerial propellers. Mees. 13883.
Ball grinding machines. Deutsche Waffen und Munitions-fabriken. 15687.

ELECTRICAL, 1911.

Trolleys or collectors for electricity. Tetlow. 19046.
Electric braking mechanism. Brüll. 19097.
Magneto electric machines. Simms, and Simms Magneto Company. 19122.
Apparatus for electrically operating and controlling planing machines. Lancashire Dynamo and Motor Company, and Wood. 19615 and 19616.
Magnetic separation of ores. Dalgleish. 19678.
Method of and means for voltage regulation in stage transformers. Richter. 20302.
Telephone installations. Lake. 20620.
Electric couplings. Michler. 24532.
Circuit connection for private telephone installations connected to telephone exchanges. Siemens Bros. & Co. 24807.

1912.

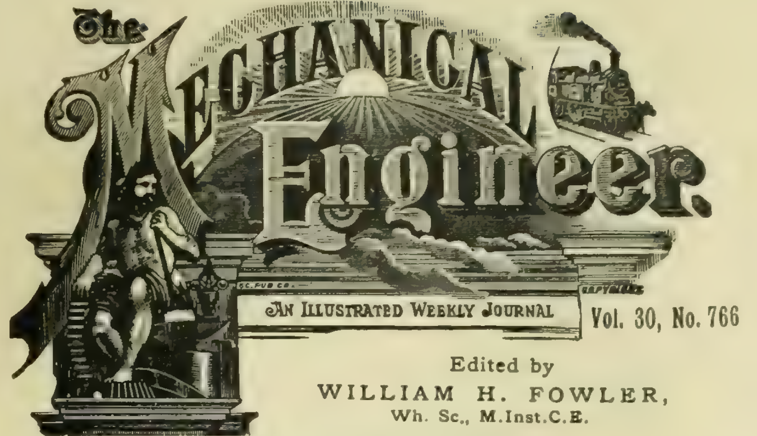
Method of connections for eliminating the influence of the temperature on the current strength of a resistance the magnitude of which increases with the temperature. Fried. Krupp Akt. Ges. 3107.
Electric storage battery plates. Ricks. 4843.
Automatic and semi-automatic telephone exchange systems. McBerty. 8573.
Automatic brakes for electric tramcars. Di Castelletto. 9466.
Electrically-heated ovens. Veritys, Ltd., and Pipkin. 10009.
Automatic telephone systems. Siemens Bros. & Co. 10539.
Apparatus for producing electric oscillations adapted for wireless communication. Dubilier. 11091.
Telephones. Graham. 13768.
Making of connections to commutator segments of dynamos. Siemens Schuckertwerke Ges. 15662.

METAL QUOTATIONS.

TUESDAY, SEPTEMBER 17TH.

Aluminium ingot	80/- per cwt.
" wire, according to sizes, &c. ......from	102/- "
" sheets " " ...... "	120/- "
Antimony .... £28/10/- to	£29/-/- per ton.
Brass, rolled	9⅛d. per lb.
" tubes (brazed)	11¾d. "
" " (solid drawn)	10d. "
" " wire	9⅛d. "
Copper, Standard	£78/10/- per ton.
Iron, Cleveland	68/1½ "
" Scotch	74/1½ "
Lead, English	£23/5/- "
" Foreign (soft)	£23/-/- "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£8/5/- per bottle
Silver	29 $\frac{3}{16}$d. per oz.
Spelter	£27/2/6 per ton.
Tin, block	£226/10/- "
Tin plates	15/3 "
Zinc sheets (Silesian)	£30/5/- "
" (Stettin; Vieille Montagne)	£30/12/6 "

Electricity at Barrow. — The Barrow electricity works are to be extended in respect of both buildings and plant. The Furness Railway Company have arranged with the Corporation to take a 10 years' supply of electricity from the public mains for the whole of their locomotive works.



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American Motor-cars.

PERIODICALLY American engineers invade this country with one or other of their specialities. Not so long ago it was light machine tools, principally lathes and milling machines; at another it was the tramway motor; and at one time there threatened an invasion of big steam engines, a threat which materialised to the extent of one or two rather fine examples of American electric-generating engines. Engineering is not the only field in which these invasions have taken place, although it is in machinery or the products of machinery that the Americans excel, and seem most fertile in devising new or improved productions. In most cases the invasions have been temporary in character. Small tools of the instrument class, such as calipers and rules, seem to have established themselves in the English market, and small machine tools of American manufacture were popular here for some years, but are now seldom in request. Railway locomotives enjoyed a very short-lived popularity, the big steam engine barely arrived, tramway material has practically ceased to come to us from America, and even boots and shoes and the machinery of their manufacture seem to have given up the struggle to capture the British market. The latest arrival is the American motor-car. Already they are here in their thousands, and so far as one can judge the incoming tide shows no sign of slackening. The question naturally arises: Is the invasion permanent or temporary? and then follows the further question, How comes it that American cars can be sold in this country at a profit and in such numbers? These two questions are more than interesting; they are important. The answer to the second question largely answers the first also, for the permanency or otherwise of the present invasion will depend mainly upon the ability of the American firms to continue to do what they are now doing, that is, sell an attractive car at a lower figure than competing British-made cars. And, conversely, if British firms in their own interest are to

see to it that the invasion is only temporary they must meet the American by offering as attractive a car at as low a price, or a definitely better car within measurable distance of the American price. It is, indeed, largely a matter of price, but to say this does not really throw much light on the situation, and may, indeed, tend to obscure the real lessons of the invasion. The price is merely the index of certain conditions, and it is these conditions which are of real importance to the British manufacturer. The low price of the American car may indicate natural advantages, superior manufacturing organisation, or some peculiarity of design. It is difficult, without comparing the prices of materials in detail, to say if the American manufacturer possesses any natural advantages. In general, materials are as costly there as here, but we have reason to believe that in the case of some of the partly-finished parts the American can buy cheaper than we in this country. This is true of the pressed steel frame, which, we believe, is purchased at a very low figure indeed. The remedy for this lies more with the steelworks than the car builder, although it is partly a matter of uniformity in design and quantities in manufacture, both of which factors it is the car-builder's business to mould so far as possible. Natural advantages or disadvantages include rates of wages and fixed charges, and in neither of these matters can we be said to be handicapped, so that on the whole the American manufacturer does not seem to possess any marked natural advantages over the British. Turning to manufacturing organisation, a close comparison is impossible, but the most cursory consideration of the light American motor-cars now being sold in this country is sufficient to convince one that the manufacturing organisation which produced them at the prices ruling is of a very high order of efficiency. Only a detailed study of the car could disclose much useful information on this subject, and this study should, if possible, be strengthened by inspection of the works and a review of the selling organisation, for, from a competitive point of view, the selling organisation is a part of the manufacturing organisation. This is particularly true of motor-cars, owing to the large percentage of the price which usually goes in commissions, agency expenses, and advertising.

It is, however, in design that the American motor-cars in this country contain the most important lesson for British firms. The distinguishing feature of the American car is lightness. This is achieved by economising material at every turn. It may or may not be true that this paring process has been carried too far. There is evidence in support of the contention that it has. American cars are said to be found stopped on the road more frequently than English and Continental makes. Such stoppages are often due to defective driving, but the *relative* number of stoppages is a fair index of the *relative* reliability under working conditions. We are not, however, concerned to demonstrate that the American car is not too light in its scantlings, but only to show that it illustrates in a striking manner the advantages of lightness. In the first place the low price of the car is partly due to its lightness. In the second, the power required to drive the car is reduced, and its hill-climbing capacity increased. The explanation of the superior climbing capacity of a light car is interesting. Car resistance is partly due to bearing, tyre, and mechanism friction, and is more or less proportional to the weight. The second factor, and probably the more important at fairly fast speeds, is the wind resistance. This is a matter of the size and form of the car, and is only dependent on the weight in so far as it affects the form and size. When climbing a hill there is added the resistance of gravity, which is obviously directly proportional to the weight of the car. The relative importance of these factors when running on the level and when climbing may be best illustrated by a hypothetical example, in which the light car has only half the weight of the heavy one, and rather more than half as much tyre, bearing, and mechanism resistance. Dividing the power P into that spent in overcoming this internal friction F, gravity (hill climbing) G, and air resistance A, we have, when running on the level:—

Heavy car ... ... $P = F + G + A$
$= 50 + 0 + 50 = 100$

Light car ... ... $P = F + G + A$
$= 30 + 0 + 50 = 80$

When hill climbing, the gears are so changed that the engine speed and power P remain practically unaltered. This also causes the internal friction F to remain practically unchanged. Hence the sum of the powers expended in lifting the car uphill against gravity G, and in overcoming wind resistance A, must also remain unaltered, since they, together with the power spent in overcoming internal friction F, constitute the total engine power P. The air friction, as we have seen, depends only on the form and speed of the car, but the hill-climbing resistance is proportional solely to the weight of the car, and the power spent in overcoming this resistance is proportional to the product of the weight and speed of the car. The division of the power between hill-climbing and air resistance obviously depends on the gradient, but a typical case is represented, as follows.

Heavy car ... ... $P = F + G + A$
$= 50 + 40 + 10 = 100$

Light car ... ... $P = F + G + A$
$= 30 + 30 + 20 = 80$

The fact that the hill-climbing power for the light car is more than half that of the heavy car is due to its greater speed. The same cause also increases its air-resistance power. Put in another way, it could climb at the same speed as the heavy car on 60 h.p. instead of its normal 80. The margin enables it to attain a greater speed on the hill. Thus:—

$P = F + G + A = 30 + 20 + 10 = 60$ at same speed as heavy car.

This example is merely illustrative, but it demonstrates the essential facts. In addition to the advantages of first cost and better hill-climbing qualities, the reduced power of the light car reduces the petrol bill. More important than these is the saving in the cost of tyre renewals. These go up rapidly with the weight of the car. The advantages sketched above are so great that every effort should be made to keep down car weight consistent with reliability. Reliability must not be confused with long life, although the two are not entirely independent. The life of a motor-car is in any case short, and the depreciation correspondingly heavy, so that a cheap car can afford to be content with a shorter life. The lightness of the American motor-car is in keeping with their other road vehicles. There are heavy American cars of all kinds, but the typical American horse conveyance for private use is a buggy, which apparently does not weigh much more than a substantial English wheelbarrow. To English eyes it seems frail in the last degree, but actually, its lightness and the freedom with which the body is slung from the thin-tyred wheels alone enable it to negotiate the trails and apologies for roads which are the rule over most of the North American Continent outside the large towns. The same conditions have necessitated leaving the space under the car below the axles free from protruding parts, a feature common to all "colonial-

type" cars. It is a good thing occasionally to have our fixed ideas challenged in vigorous fashion, just as the American motor-car is doing now. If we study the attack carefully it may do us a world of good, and more than compensate for the trouble and worry which an invasion necessarily involves.

EFFICIENCY OF WORM GEARING FOR AUTOMOBILE TRANSMISSION.*

BY WM. H. KENERSON.

THIS investigation was made at the plant of the Brown and Sharpe Manufacturing Company for the purpose of determining the efficiency of three types of worm gearing for use in an automobile transmission system and the heating effect due to continuous running. The power for these tests was obtained from a 50 h.p. induction motor, running approximately 870 revs. per minute at full load.

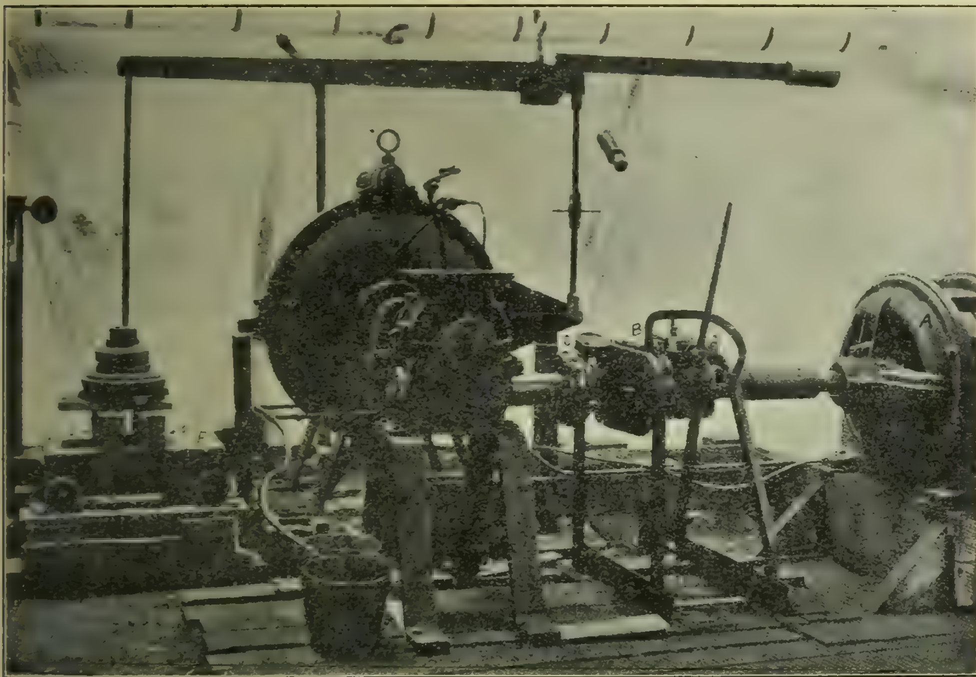


FIG. 1.—APPARATUS FOR TESTING WORM GEARS.

Between the motor and the worm gear case was placed an automobile transmission gear case to enable tests to be made at two lower speeds. Between this and the worm gear case was placed a transmission dynamometer designed by the author. An Alden brake was used to absorb and measure the power transmitted by the gears under test. Fig. 1 shows the whole apparatus mounted ready for testing the worm gear efficiency. A is the motor, B the automobile transmission gear case, C the transmission dynamometer, D the case containing the worm gear under test, E the Alden brake, and F the platform scale which measured the load on the Alden brake.

The apparatus was so arranged that as the load was imposed the weight on the platform scale was removed and all vibration of the scale beam was eliminated by interposing springs S between the blocks F F, which sustained the weight on the scale, and also by suspending by a wire from the weight at the end of the scale beam a plate which dipped into a pail of oil, thus acting as an efficient dashpot. It was found possible by careful manipulation to maintain a steady and easily read load on both the transmission and absorption instruments.

The transmission dynamometer and brake were first compared by running them at various loads, and the torques corresponding to horse-power per 100 revs. per minute marked on the dial of the transmission instrument corresponding to similar loads as indicated on the brake. It is evident that by this method of comparison the two instruments must check each other exactly. A thermometer placed in the oil well at the back of the worm gear case D indicated the temperature of the oil, and another thermometer placed on the wall near the apparatus indicated the room temperature. The oil employed to lubricate the gears was one intended for use with superheated steam, having a specific gravity of 26 Baumé, flash point 625° Fah., and viscosity at 212°, 260° to 265°. The case contained about 5 quarts of the oil.

In all the trials the worm was located underneath the gear. Fig. 2 shows sections through the gear case. As indicated, both shafts are mounted on ball bearings and end-thrust ball bearings take care of the thrust on the worm and wormwheel. All the worms were made of machinery steel, case-hardened, and the wormwheels of phosphor bronze. The first worm and wheel tested is shown in Fig. 3. This pair of gears is an unusual case of the worm and wormwheel. The smaller gear is hobbed with a hob of the size of the larger gear, thus making possible adjustment of the larger gear, which would not otherwise be the case. While in appearance this gear resembles a Hindley worm, it is not such in reality. Although not strictly in accordance with usage, the smaller gear will be called the worm and the larger the wormwheel in the following description. The wormwheel was cut with the cutter shown in Fig. 3, and the shape of the teeth on a section through the worm and wormwheel, parallel to the axis of the worm, is also shown.

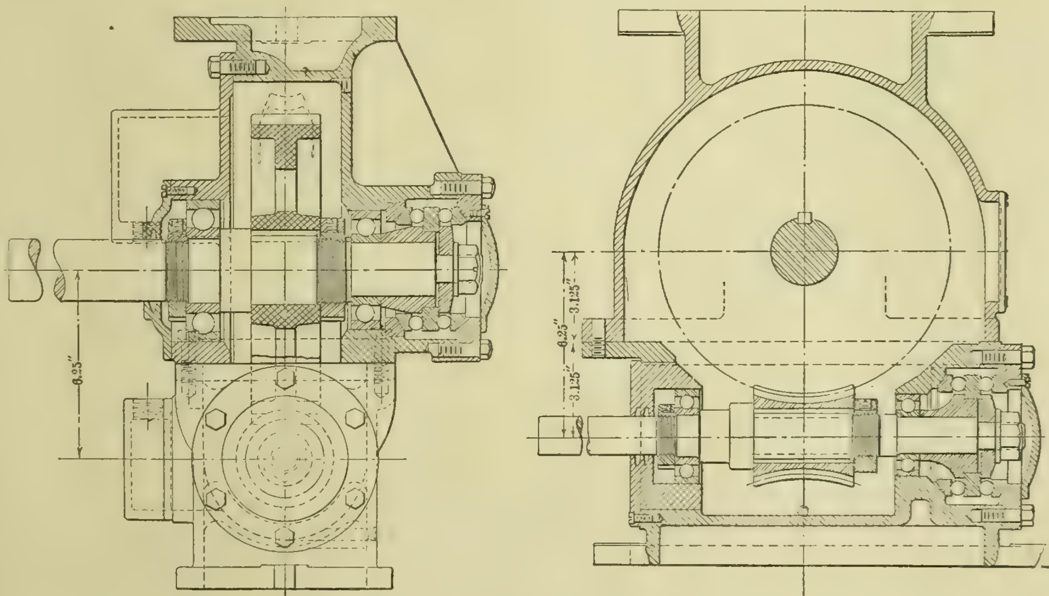


FIG. 2.—SECTIONS THROUGH GEAR CASE.

All necessary information pertaining to pairs No. 2 and 3 is given in Fig. 4. The difference between gears 2 and 3 is principally one of shape of the worm threads. This difference is clearly brought out in the sections of the worm and wheel shown in Figs. 5 and 6. The shape of the teeth on the worm in Fig. 5 was produced with a cutter, the included angle of

* Abstract of paper presented before the American Society of Mechanical Engineers.

which was 29°, and the depth of tooth 0·570in. This depth was based on the axial pitch, when the usual method on multiple worms is to base the depth on the normal pitch. The object in using this cutter was to obtain as many teeth as possible in contact at one time, and also a shape that could be ground with a straight-sided emery wheel. The teeth of the worm in Fig. 6 were cut with a cutter shaped as shown, which is an arbitrary shape made to produce at one instant the greatest effective breadth possible, as shown in the figure.

FIG. 3.—NO. 1 WORM AND WORMWHEEL.
Wormwheel, phosphor bronze. No. of teeth, 43 L.H.; Pitch diameter. 10·95; Outside diameter, 11·28; Circular pitch, 0·800; Angle of teeth with axis, 45°; Normal circular pitch, 0·5657; Pitch of cutter, 5·553; Addendum, 0·1628 (not standard); Thickness of tooth, 0·282; whole depth, 0·3882; Included angle of cutter, 45°.

In conducting the trials the load was maintained at the desired point by one observer who adjusted the brake. Readings were then taken on the transmission instrument by two independent observers. The speed of the motor was observed in each case and from this, knowing the gear ratio, all the other speeds were easily computed. Temperatures were taken immediately following each series of observations.

TABLE I.—*Efficiency Test of No. 2 Worm Gears when on Direct Speed.*

R.P.M. Motor.	R.P.M. Worm.	R.P.M. Worm Gear.	Speed of Worm in. Ft. per Min.	Initial Load.	Reading on Scale.	Load on Brake 315 Ft. Radius.	H.P. per 100 R.P.M. Brake.	Total Brake H.P.	Total Trans. Dyn. H.P.	Efficiency of Worm Gears.	Transmission Dyn. Reading.				Temp. at End of Test		Time.		Duration.
											1	2	3	Av.	Oil	Room	Start	Fin.	
875	875	196·9	690·7	104	55	49	24·5	48·24	49·26	97·9	5·6	5·65	5·65	5·63	268	65	10:14	10:20	6
873	873	196·4	689·1	104	60	44	22·0	43·22	44·35	97·5	5·1	5·05	5·1	5·08	273	65	10:20	10:25	5
880	880	198·0	694·6	104	65	39	19·5	38·61	40·92	94·4	4·7	4·65	4·6	4·65	276	66	10:25	10:30	5
880	880	198·0	694·6	104	70	34	17·0	33·66	36·26	92·8	4·15	4·1	4·1	4·12	275	66	10:30	10:33	3
883	883	198·7	697·0	104	75	29	14·5	28·81	31·17	92·4	3·55	3·55	3·5	3·53	273	66	10:33	10:37	4

For purposes of comparison a series of trials was run on a pair of bevel gears, the principal dimensions of which are shown in Fig. 7. Table I. is a record of one set of observations typical of the series. Table II. is a summary of the results of all the trials, and the curves of Fig. 8 show in

FIG. 4.—NOS. 2 AND 3 WORM AND WORMWHEEL.
Wormwheel, phosphor bronze; Number of teeth, 40; Pitch diameter, 10·5704; Throat diameter, 10,9964; Circular pitch, 0·8302; Angle of teeth with axis, 38° 16′ 5″; Normal circular pitch 0·6518; Pitch of cutter, 4·8196; Addendum, 0·213; Thickness of tooth, 0·3568; Whole depth, 0·4586; Worm: Aurora Street, case-hardened; Number of teeth, 9; Pitch diameter, 3·015; Outside diameter, 3 441; Circular pitch, 1·0524; Angle of teeth with axis, 51° 43′ 55″; Thickness of tooth, 0·295; Head, 7·4719; Ratio of wheel to worm, 40 to 9.

TABLE 2.—*Worms and Wheels and Bevel Gears, average Efficiencies taken.*

GEAR NO. 1

	R.P.M.		H.P.		Temp.		Eff.
	Worm	Worm Wheel	Input	Output	Oil	Room	
FIRST SPEED	254 2	65.03	26.18	24.06	206	73	91 9
	254 6	65.13	24.75	22.47	217	73	90 8
	254.5	65 11	22.98	20 81	225	73	90.5
	255.1	65.25	21.17	19 25	228	73	90 9
	255.3	65.30	19 56	17 63	232	73	90 1
	255.7	65.41	17.76	16 02	233	74	90 2
	255.9	65 48	16.00	14.41	233	74	90 1
	256.3	65 60	14 34	12 79	233	74	89 4
	256.5	65.62	12 37	11 15	231	74	90 2
	256.8	65.69	10.55	9.53	229	74	90 2
SECOND SPEED	545.2	139.5	43.48	41.16	178	73	94 8
	546.9	139.9	40.51	37.78	207	70	93.0
	547.8	140.1	36.88	34.33	214	70	93 2
	548.8	140.4	33 47	30 89	217	70	92 3
	550.2	140.7	29.76	27 44	218	70	92.3
	550.5	140.8	26.01	23.94	218	71	91.3
	551.1	141.0	22.22	20.45	217	71	92.0
DIRECT	859.5	219.8	66 43	64.86	178	69	97.6
	864.5	221.1	62.89	59.71	201	70	94.9
	871.0	222.8	59.23	54.60	214	70	92.2
	874.5	223.7	54.22	49.22	224	70	90.8
	878.0	224.6	48.60	43.80	230	70	90 1
	882.0	225.6	42.25	38.36	233	70	90 8
	884.0	226.1	36.24	32.79	237	71	90 5

GEAR NO. 2

	R.P.M.		H.P.		Temp.		Eff.
	Worm	Worm Wheel	Input	Output	Oil	Room	
FIRST SPEED	254.7	57 32	19.26	18.34	164	69	95.3
	254 7	57 32	17 99	16.91	169	69	94.1
	254.5	57 25	16 73	15.46	162	68	92.5
	254 3	57 22	15.08	14.02	142	69	93.1
	255 1	57 39	13.52	12.63	159	69	93.5
	254 9	57 35	12.14	11 18	160	69	92.2
	254 8	57 34	10.69	9 75	160	69	91 4
SECOND SPEED	544 2	122.4	36 95	36 11	178	70	97 7
	545 0	122 6	34 61	33.10	184	70	95.6
	546 7	123 0	32.09	30.14	188	70	93 9
	548 4	123.4	28.90	27 15	187	70	93 9
	549 0	123 5	25 80	24.08	186	71	93.3
	549 6	123 7	22 59	21 03	163	70	93 1
	551 0	124 0	19 12	17.98	163	70	94 0
DIRECT	873.5	196.5	49 35	48 14	265	66	97 5
	875 0	196.9	44 50	43 30	256	65	97 3
	878.0	197.5	40.40	38 50	260	66	95.2
	881.0	198.2	36.40	33 70	261	66	92.4
	883.4	198.8	30 73	28.84	262	66	93.8

GEAR NO. 3

	R.P.M.		H.P.		Temp.		Eff.
	Worm	Worm Wheel	Input	Output	Oil	Room	
FIRST SPEED	254.1	57 19	18.75	18.30	136	79	95.5
	254 8	57.33	16.54	15 48	144	79	93.1
	255.0	57.38	13 75	12.62	149	79	91.8
	255.4	57.47	10.80	9.77	150	79	90.5
	255 6	57 52	7.38	6.90	149	79	93.6
SECOND SPEED	543 2	122 2	38.59	36.06	204	77	93 4
	543 8	122.4	35.36	33.04	215	77	92.4
	544 8	122 6	33 12	30.03	219	77	90.7
	545 8	122 8	29 82	27 02	221	77	90.6
	546 5	123.0	26 70	23 98	222	78	89.8
	547 2	123 2	23 56	20 95	222	78	88 9
	548 3	123.4	20.02	17.89	221	78	89.4
DIRECT	866.0	194 8	49 95	47 72	215	77	95 5
	868 2	195 3	45.68	42.98	223	77	94.1
	870.8	195 9	41.20	38.20	228	77	92.7
	874.0	196 7	36.88	33.45	230	77	90 6
	876.0	197 1	31.45	28.60	230	78	90 9
	878 8	197.7	26.45	23.73	229	78	89.7

BEVEL GEARS

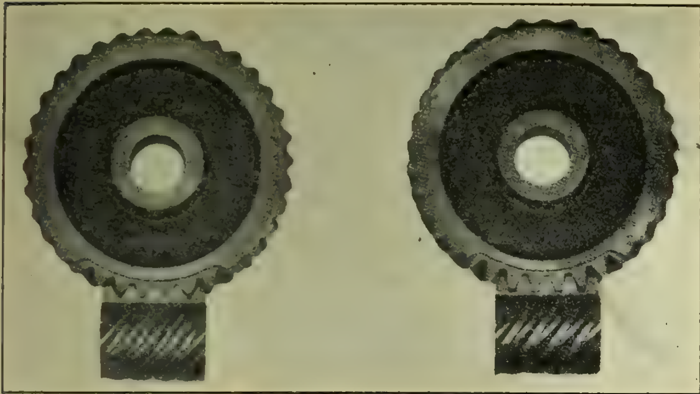
	R.P.M.		H.P.		Temp.		Eff.
	Pinion	Gear	Input	Output	Oil	Room	
FIRST SPEED	254.2	68.43	20.92	20.19		70	96.6
	254.5	68.51	17.50	16.78		70	95.9
	256.1	68.95	14.54	13.44		69	92.4
	256.5	69.05	10.95	10.01		70	91.4
SECOND SPEED	541.8	145.0	39.64	39 37		67	99.3
	544.1	146 4	33 43	32 22		67	96.4
	545 7	146 9	26.25	24 98		67	95.2
	548 5	147 6	18 75	17 72		67	94.5
DIRECT	872.0	234.7	52.05	51 63		70	99.2
	878.6	236.6	42 09	40 22		70	95.5
	884 4	238.2	30 40	28 58	132	79	94.0

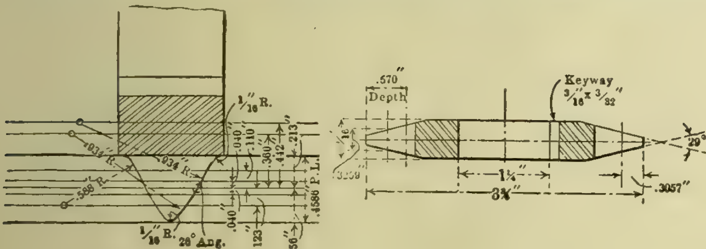
graphic form the average efficiency of the different gears at the various loads and speeds.

Number of Groups of Readings taken in Table II.

	Gear No. 1	Gear No. 2	Gear No. 3	Bevel Gear.
First speed..........	4	5	5	3
Second Speed	4	5	5	6
Direct	3	5	5	5

Total separate readings, 165.





FIGS. 5 AND 6.—SECTION OF NOS. 2 AND 3 WORM AND WORMWHEEL.

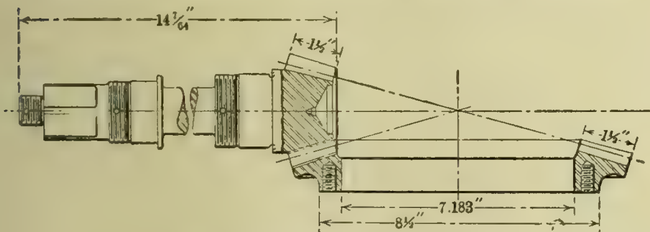


FIG. 7.—DRIVING GEAR AND PINION.

Driving Pinion, 5 per cent. Nickel Steel, case-hardened; Pitch, 5; Number of teeth, 14; Angle of edge, 15° 4'; Angle of face, 71° 5'; Outside diameter, 3·3359; Driving gear, 5 per cent. Nickel Steel, case-hardened; Pitch, 5; Number of teeth, 52; Angle of edge, 74° 56'; Angle of edge, 13° 47'; Outside diameter, 10·4627.

In conjunction with the efficiency trials a series of runs was made to determine the heating effect due to continuous running. In these trials, which were in effect endurance tests, a constant load was transmitted through the gearing and the temperature of the oil in the gear case and the temperature of the room noted at frequent intervals. From these observations it was found that at the beginning of the run the oil temperature rose rapidly and somewhat irregularly. As the run continued, however, the rise became much more gradual and regular. In the runs where the smaller amounts of power were transmitted a point was reached where the temperature remained constant. This indicated that radiation was sufficient to carry away the heat due to power lost through friction in the gearing, or in other words that the gears would run indefinitely at the load. The heat curves of the No. 1 worm and gear are shown in Fig. 9.

The higher loads indicated were abnormal for the gears under consideration and would not occur in any use to which the gears would normally be put. The fact that these trials continued for from 60 to 80 minutes without failure indicates that the structure is both strong and enduring and that should such temperatures be reached for any accidental reason the gears would not be destroyed. The result of the trials was of particular interest because of the very high efficiency and

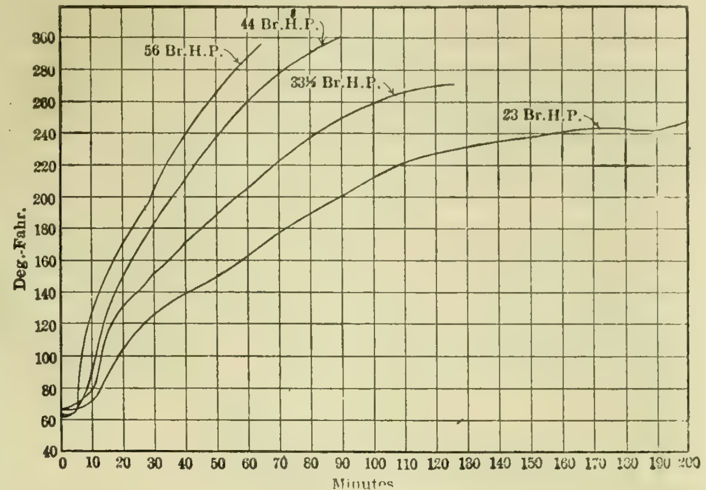


FIG. 9.—HEAT CURVES.

carrying capacity of the gears tested. Every possible precaution was taken to secure accuracy in the results, and the high degree of accuracy obtained is due largely to the skill and care of Mr. B. F. Waterman, of the Brown & Sharpe Manufacturing Company, under whose personal supervision the apparatus was erected and all the trials were conducted.

A British 34-knot Cruiser.—All speed records for large ships have been lowered by the new British battle-cruiser "Princess Royal," which on Saturday last returned to Devonport on the completion of her experimental trials. She obtained a speed of 34 knots, or 39 miles an hour, which constitutes a world's record. Since undergoing her official full-power trials, in which she obtained a speed of 32·7 knots, she has been docked and fitted with a new type of three-bladed propeller. To test these propellers she made six runs at three-quarter power and six at full power on the measured mile off Polperro, on the Cornish coast. The second ship in point of speed is the "Princess Royal's" sister, the "Lion," which has done 31 knots. The "Princess Royal's" contract speed was only 28 knots. Her contract horse-power was 70,000, obtained with turbine engines driving four propellers, but it is stated that this was exceeded during the trials.

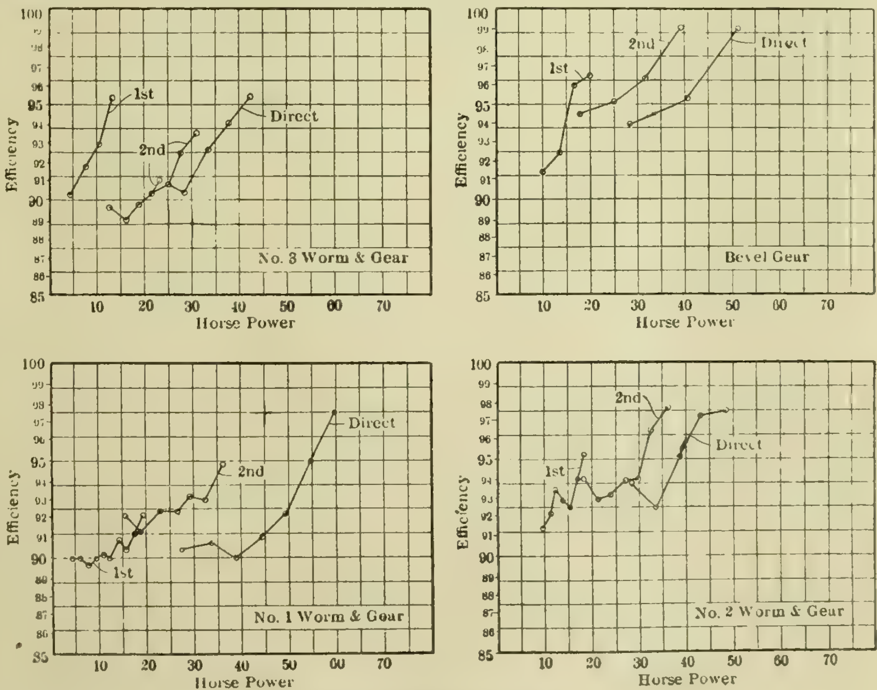


FIG. 8.—EFFICIENCY CURVES.

ARRANGEMENT AND DISPOSITION OF PARTS OF INTERNAL-COMBUSTION ENGINES.

A method of constructing horizontal internal-combustion engine frames so that the engine can be multiplied if desired and also to allow of certain units being run if others fail has recently been patented by Mr. W. J. Gold, Mr. F. W. Beeching, and Messrs. Kynoch, Ltd., Witton, Birmingham. The method of constructing the frame of the engine for a single-cylinder unit consists in providing a U girder down each side extending L shape in plan to the centre line of the engine in front, the cylinder being bolted down to each of the U girders at the back and bolts passed through the two halves at the front to hold them rigidly together. A bolt is also passed through the bedplate under the cylinder. The cylinders are secured in their correct position by round keys, the holes for which are drilled half into bedplates and half into the cylinder. Similarly the main bearings are kept in accurate alignment by two round keys, one being fitted vertically and one horizontally at the front joint.

If it is desired to extend this engine, one side of the frame is removed and a wider U girder substituted, sufficient to bolt two cylinders on to and T shaped in front extending to the

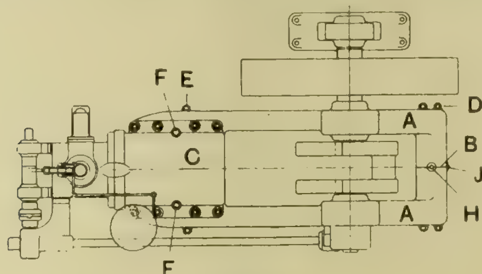


Fig. 1.

centre lines of the two cylinders, the side which was removed being placed on the outside as before and bolts passed through the whole, both in front and under the cylinders to secure the parts together. By continuing this method any number of cylinders may be used. The cam shafts are arranged all in one line and coupled together by concentric couplings of the Oldham or similar type, so that in the event of breakdown of the gear for any cylinder a piece of cam shaft may be taken out and replaced by a plain piece of shaft with couplings, the connecting rod of that unit being uncoupled and the other units continuing to run, thus disposing of the necessity of having a standby set. Having couplings of this type makes the portion of shaft between any two bearings complete in itself, thus obviating the necessity of having a long cam shaft accurately in alignment. The admission valve gear is controlled by a governor common to any number of units. In this construction any cylinder is complete in itself with its gas and air connections, so that any part of one unit may be used for a similar place in any other unit.

Fig. 1 shows the method of constructing the frame for a single cylinder unit, in which A A are the U girders one down each side extending L shape to the centre line in front at B, the cylinder C being bolted down to each of the U girders at

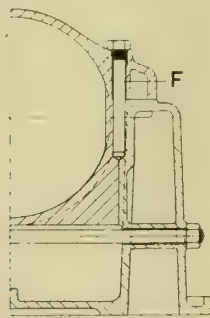


Fig. 2

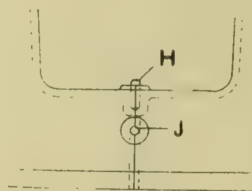


Fig. 3.

the back and bolts D passed through the two halves at the front to hold them rigidly together. A bolt E is also passed through the bedplate under the cylinder. The cylinders are secured in their correct position by round keys F, shown in detail in Fig. 2, and also indicated by F, Fig. 1; the holes for these are drilled half into bedplate and half into cylinder. Similarly the main bearings are kept in accurate alignment by two round keys H and J, Fig. 3, shown also in Fig. 1 at H and J, one being fitted vertically and one horizontally at the front joint. If it is desired to extend this engine, one side of the frame A, Fig. 1, is removed and a wider U girder substituted as at L, Fig. 4, sufficient to bolt two cylinders on to and T shaped in front extending to the centre lines of the two cylinders, the side

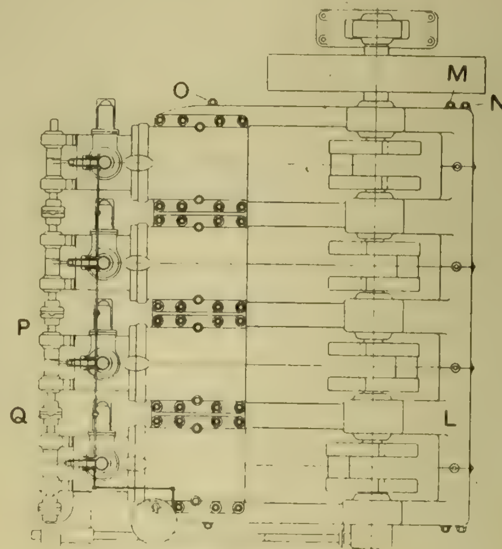
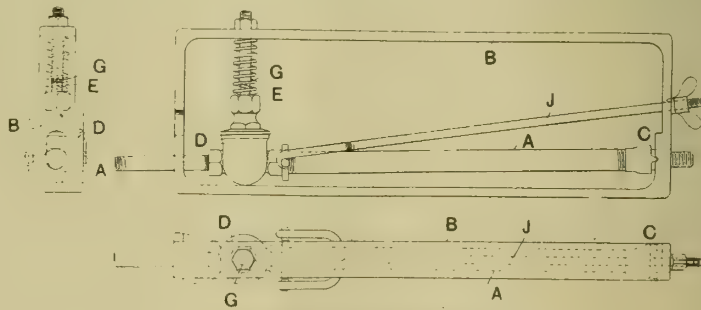


Fig. 4.

which was removed being placed on the outside as before and bolts M, N, O passed through the whole, both in front and under the cylinders to secure the parts together. By continuing this method any number of cylinders may be used. Coupled cam shafts P are employed common to any number of cylinders, Fig. 4, each set of cams being separated by concentric couplings of the Oldham type as shown at Q, Fig. 4, so that in the event of breakdown of the gear for any cylinder, a piece of cam shaft may be taken out and replaced by a plain piece of shaft with couplings.

LORD & BARLOW'S STEAM TRAP.

The accompanying illustrations show a design of steam trap of the class in which the steam valve is automatically regulated by a tube expanding or contracting according to the heat of the steam or water passing into and through the tube. This arrangement, the joint invention of Mr. G. S. Lord, Clarendon Works, Moss Lane, Whitefield, and Mr. P. Barlow, comprises a frame B in which is fitted a tube A flexibly connected at one end to the frame at C in such a manner that the tube is securely connected to the frame, but is not rigid and allows the opposite end of the tube to have a small amount



Lord & Barlow's Steam Trap.

of free movement vertically. The opposite end of the tube A is flexibly connected to a valve casing D in which is the seating and valve; the spindle E of the valve is of such a length that it engages a stud G fixed in the frame and closes the valve, when by the expansion of the tube A the valve casing is caused to rise by the length of the tube being restrained by the end of an adjustable inextensible rod J fixed to the frame, the opposite forked end being connected either to the opposite end of the tube as shown or to the valve casing D; the weight of the frame is counterbalanced by the spring on the stud G.

MARINE PROPULSION BY ELECTRIC TRANSMISSION.*

BY HENRY A. MAVOR.

AT the Portsmouth meeting of the British Association in September, 1911, the present writer submitted a communication on "Electric Drives for Screw Propellers." Since that date some further developments have occurred. The first of the three propositions of which details were given has been superseded by an ordinary reciprocating engine equipment. The United States law requires that the machinery for ships which are to sail under the American flag must be built in the country, and it was found that the comparison of cost was unfavourable under this condition. The second proposition, an oil electric tank barge for Canadian service, is now under construction; the details of the machinery equipment form part of this communication. The third proposition is still on paper only, but the United States Government has ordered an equipment closely resembling that described. This equipment has been constructed by the General Electric Company of America. Descriptions of this plant have already been published by Mr. W. L. R. Emmet, the designer, in papers contributed to the Society of Naval Architects and Marine Engineers in America and to the American Institute of Electrical Engineers. The following is a summary of these papers:—

The "Jupiter" is one of three colliers being built for the United States Government. They are to be called "Cyclops," "Neptune," and "Jupiter." The "Cyclops" is equipped with reciprocating engines, the "Neptune" with a steam turbine connected to the propellers by gearing, and the "Jupiter" with a steam turbine connected to the propellers by electric transmission. These ships have a displacement of about 20,000 tons, and carry something like 12,000 tons cargo. The speed is 14 knots. The "Cyclops" has already been tried on a 48-hour trial at an average speed of 14·6 knots, with a coal consumption, for the main engines only, of 1·485lbs. per indicated horse-power hour, total average indicated horse-power of both engines for the run being 6,705. The average rate of propeller revolution was 92 per minute. The results of the trials of the "Neptune" are not yet complete. It is reported that the gearing works in an entirely satisfactory manner, but that the efficiency of the turbine and propellers has not yet proved so good as expected. The following table shows comparisons of the known data concerning the equipments of these three vessels:—

	"Cyclops."	"Jupiter."	"Neptune."
Displacement tons	20,000	20,000	20,000
I.H.P. at 14 knots	5,600	—	—
Engine or turbine speed at 14 knots	88 r.p.m.	2,000 r.p.m.	1,250 r.p.m.
Propeller revolutions per minute at 14 knots ...	88	110	135
Weight of driving machinery in tons.........	280	156	Not known
Character of driving machinery...............	Two triple-expansion engines.	One turbo-generator and two motors.	Two turbines each with gearing.
Steam consumption in lb. per shaft h.p. hour	14 estimated	12 tested.	Unknown.

The collier "Jupiter" is being built at the Mare Island Navy Yard. The electric propelling machinery is now complete, and has been tested in the shops. The generating unit consists of a 6-stage Curtis turbine connected to a bipolar alternator. The speed of the generator at 14 knots is about 2,000 revs. per minute, and the voltage about 2,200. This generating unit delivers electricity to two motors, one coupled directly to each propeller shaft. These motors have 36 poles, therefore the ratio of synchronous speed reduction is 18·3 to 1, the propeller at 14 knots being designed to operate at 110 revs. per minute.†

The writer saw this plant officially tested at Schenectady in the summer of this year. For the purpose of the test the apparatus was erected in the General Electric Company's power station at Schenectady. The turbine was connected to a condenser and one motor installed in the position relative to the switchboard and controlling mechanism which it will occupy on board the ship. The other motor was arranged as a generator, and directly coupled to the first motor so as to afford a load for it. With this generating motor as load the conditions of service can be approximated, although they are more difficult than the driving of a propeller, because the load falls off only slightly with diminutions of speed and constant exciting current. With the apparatus so installed the processes of starting, stopping, speed variation and reversal can be accomplished very much as they would be on board ship, and the time and difficulty involved can be correctly judged. The motor can be operated at its full load or any desired proportion of its load and at any desired speed. Variation is accomplished by a mechanical action of the governing mechanism of the turbine equivalent to that which would be used on board ship. These arrangements afford means of experimenting with the operating conditions up to about half load, the work being applied to one motor only, the second machine being used as a generator, the current from which is carried to an artificial resistance for absorbing the energy. This device is necessary because the absorption of 7,000 h.p. on the propeller shaft is beyond the resources of existing mechanical power-wasting devices. On the other hand, it is easy to provide means of ascertaining the working conditions as applied to the generating unit, because it is easy to absorb the power of the electric generating unit in artificial water resistances. The water rates of the generating unit have thus been tested in all loads and conditions, and the record of these tests is shown by the accompanying curves.‡ In these tests the effects of speed, voltage, vacuum, and superheat are all thoroughly investigated in a series of tests run under the conditions of load characteristic of the ship's operation. Experience gained on these tests has suggested modifications by which it is anticipated that the rate can be reduced from 12lbs. to 11¼lbs. per shaft horse-power hour.

The following operations were carried out in the shop trials: (1) Start turbine by opening throttle, the speed being

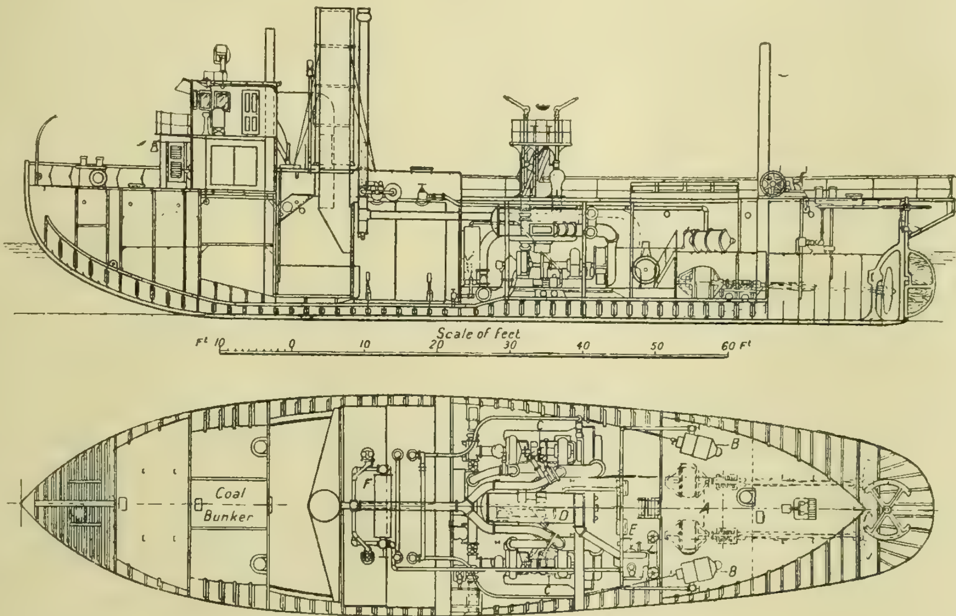


FIG. 1.—ELECTRICALLY-DRIVEN FIRE FLOAT "GRAEME STEWART."

* Abstract of paper read before section G of the British Association.

† An illustrated description of this vessel appeared in our issue of August 30th. See p. 251 ante.

‡ These curves were reproduced in our issue of August 30th. See p. 251 ante.

shown by an indicator on the switchboard; (2) bring turbine to moderate speed by movement of dial controller, adjust the motor resistance, and start the motor by closing "ahead" switch; (3) reverse the motor repeatedly by simply throwing over the switches with the speed and load corresponding to about 8 knots; (4) increase the speed and adjust the load to correspond to the maximum, which can, with the normal speed and voltage of the generator, be run with resistance in, this being the maximum speed which would ordinarily be used in "backing and filling"; (5) cut resistance out of circuit by slowing down the generator, opening the field, throwing a resistance lever, and again closing the field switch; (6) increase the speed to 14 knots and adjust the load to correspond; (7) reduce the load to about half, which corresponds to the maximum load on the ship after reversal, then reverse the motor by interrupting the field, throwing the resistance lever, change from "ahead" to "reverse" position of the switch, and again close the field; (8) stop the motor and start with resistance; (9) reverse with resistance.

These operations cover all the conditions likely to be met with in service, and all of them were repeated and varied, showing complete facility of handling the equipment. The reversal particularly was easily and smoothly accomplished. The writer took no specific records of the time required to produce the reversal. This would require special apparatus, because it was so short that it could not be conveniently observed by means of a stop watch and visual observation.

In the writer's preliminary studies on this question he considered it necessary to deal with the question specially from the point of view of propeller efficiency. Further experience has shown that in most of the cases with which he has been called upon to deal, the propeller conditions are determined by the conditions under which the ship has to work in respect of draught, &c., so that there are not many cases where the saving in propeller efficiency is a fundamental determining factor in the choice of electric equipment. The question of propeller efficiency, however, is still so closely associated with the proposals for ship propulsion, that the writer suggested to Mr. Emmet the examination of the propeller conditions on a small electric vessel constructed by the General Electric Company as a fire-boat for the city of Chicago. This vessel, the "Graeme Stewart," is one of two boats owned by the city of Chicago. They are equipped with General Electric turbines, which drive centrifugal fire pumps. These steam turbines are also connected to direct-current generators, and each of the twin screw propellers is driven by an electric motor. The boat is 120ft. long, 28ft. beam, 10ft. draught, and the general arrangement of the equipment is shown in Fig. 1. It is interesting as another example of electric propulsion, although in this case the methods are different from those here discussed. Mr. Emmet has published the results of these experiments in a paper to the Society of Naval Architects and Marine Engineers, held in New York in November of last year. These results are of more than academic interest, for they show clearly, in a way not hitherto possible, the relation between the power applied and the work done under the varying conditions produced by the manœuvring of a boat of considerable size. Similar experiments were carried out on a smaller scale in connection with the design of the propellers for the "Mauretania" and "Lusitania," and there is evidence that electric transmission will provide means for a fuller understanding of propeller action than can be obtained from small-scale experiments in a tank. Mr. Emmet's paper is accompanied by a very full set of curves, to which those interested are referred. To complete the understanding of the curves in Mr. Emmet's paper it may be stated that the torque given is the torque on each shaft, and the power is the sum of the power of both propellers. The weight of the rotor of each motor is 4,150lbs. The radius of the motor armature is 15¾in. The torque as given on the curves is reduced to 1ft. radius, and is the total torque developed by the motor inclusive of the torque for accelerating the armature, the shaft, and the propellers.

Returning to the Canadian vessel, the arrangements shown in the drawings accompanying the writer's paper to the association at Portsmouth last year have been somewhat modified in carrying them into actual form. It has been found more convenient to arrange the generating plant in two units, as shown in the accompanying drawings (Fig. 2). The general principle of the apparatus is as described in last year's paper. This is one of the cases where the limitations imposed by the conditions of service are such that the best results are obtained by adopting the propeller size and rate of revolution which have been determined by experience in working with steam. The locks on the canals on the Great Lakes route from the St. Lawrence impose limitations on the length, breadth, and draught of the ship, which determine its size and the size of the propeller. The manœuvring of the ship by the steam arrangements is satisfactory, and therefore the field for improvement is limited to the increase of carrying capacity. The present arrangement results in an increase of about 250 tons in the carrying capacity as compared with the steam equipment: (1) Due to the absence of the boilers and consequent reduction in space and weight of machinery; (2) due to the important difference in the heat value of the fuel and the efficiency with which it is used, so that the bunker capacity can be materially reduced.

The vessel as now designed has dimensions:—

Length overall	256ft.
Length between perpendiculars	250ft.
Extreme breadth	42ft. 6in.
Depth moulded	19ft.
Forecastle	38ft.
Poop	42ft.
Speed	9 knots.

The vessel is designed for and is estimated to carry about 2,400 tons deadweight of cargo, fuel, fresh water, and stores on 14ft. mean draught in fresh water. She is classified for service on the Canadian canals, Great Lakes, St. Lawrence River and Gulf, with occasional trips to Sydney, Cape Breton. Two steam boilers are provided for the working of the deck equipment, steering gear, and electric light, and for the supply of heat for the living quarters. It may at first sight seem out of place to return to steam equipment for these services, but the conditions of the service in question are such as to call for an auxiliary equipment at small capital cost. The season is short and the amount of work called for from the auxiliary equipment is small, and therefore, although an electrical equipment would be much more economical in working, there is not time or opportunity for the more economical plant to justify the increased capital expenditure, which is very considerable.

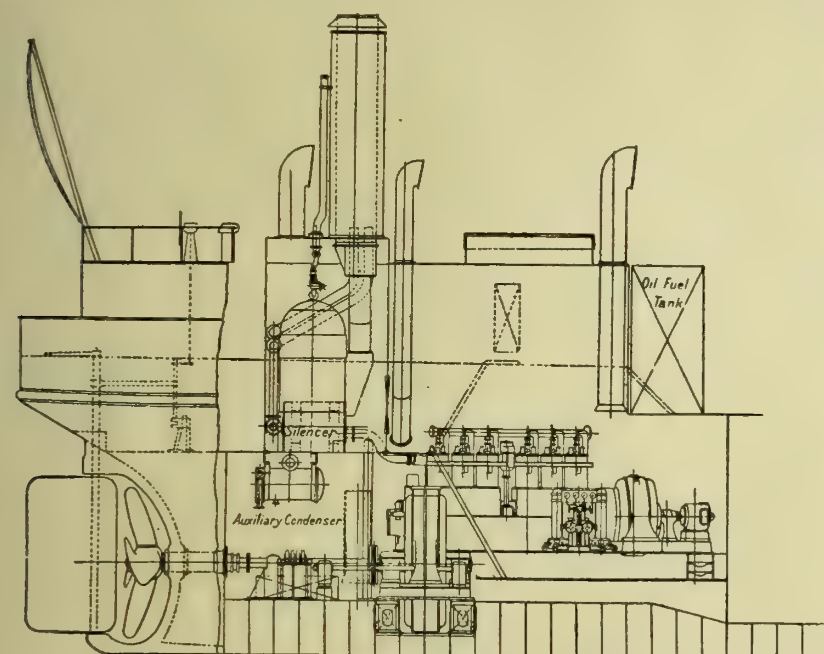
The necessity for providing steam for heat has also a strong bearing upon the question at issue. If the steam boiler has to be used it involves but little additional expense to provide steam for the steering gear, electric light, and whistle. The boilers are oil-fired, and the fuel and working pressure are in perfect control. The same fuel is used in the boilers as in the internal-combustion engines. The main machinery equipment is, as has been stated, in two units, each consisting of an engine, dynamo, and a winding on the propeller motor. The engine is of the high-speed type, which has been developed by Messrs. Mirrilees, Bickerton, & Day. Large numbers of these engines have been made and their capabilities thoroughly demonstrated, so that there is little that is experimental in the use of this plant for the purpose intended.

The engine works on the Diesel 4-cycle principle, and has the following main dimensions: Cylinders, 12in. diam.; stroke, 13½in.; revolutions per minute, 400. There are six cylinders, and the cranks are so arranged that the firing takes place at equal intervals. The engine consists principally of a bed-plate, on which are mounted the columns carrying the cylinders with their heads and valves. The cylinder head contains the valves which are operated by levers and cams. A special feature of the levers for the air, exhaust, and fuel cams is that they are split in such a manner that the part above the valves can be swung back, so that the valves can easily be removed without disturbing any other gear. The working parts of the engine are entirely enclosed, and a system of forced lubrication is used, supplied by a valveless pump driven by an eccentric on the crank shaft placed at the compressor end. The second motion shaft is

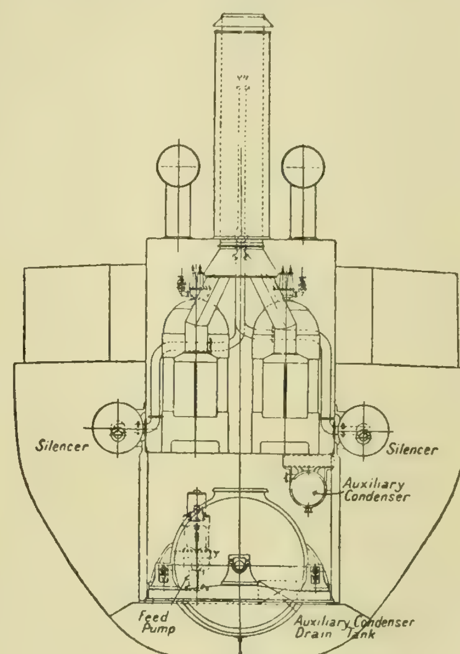
driven by means of a worm wheel mounted on the crank shaft directly midway between the centre cylinders, through a vertical shaft which also carries the governor at its upper end. On the second motion shaft, which is placed at the front of the engine and carries the cams for operating the valves, are mounted the eccentrics which drive the two fuel pumps, there being a separate pump for each cylinder. This arrangement enables the power to be very equally divided between the cylinders. The compressor is driven directly from the main crank shaft, and is mounted in the bed-plate, which is extended to carry it.

The starting of the engine is effected in the usual Diesel manner, by means of compressed air stored in receivers placed in a handy position near the engine. The compressed air for this purpose is supplied by the compressor on the engine, which also supplies that required for blowing the fuel oil into the cylinders. The engine is provided with a patented device for preventing the accumulation of fuel oil in the fuel valves which are inoperative during starting. A small flywheel is fitted of sufficient weight to ensure steady running, and to facilitate barring round when required. It is bolted to a flanged coupling forged solid with the crank shaft. Cooling water is circulated through the cylinder and compressor jackets by a pump of the rotary type, which draws direct from the sea. This pump is driven by mitre gearing from the compressor end of the crank shaft. The exhaust pipes also are water cooled. The air for the main cylinders is drawn through the bed-plate, thus effectually silencing the suction. In the normal operation of the ship the engines run under governor control at 400 revs. per minute, but the speed of revolution can be adjusted by manipulating the governor, so that the engine may maintain constant revolution per minute at a rate considerably below 400 should this be required.

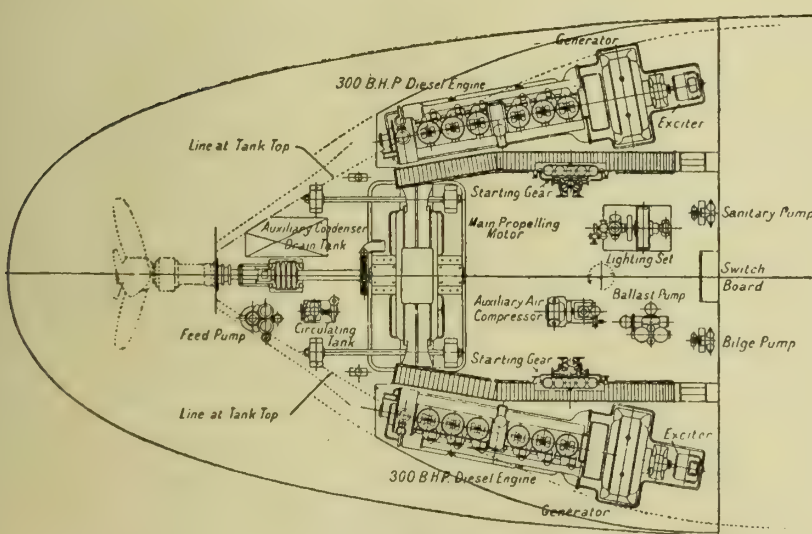
The electric equipment consists of two 3-phase generators each giving about 235 kilovolt-amperes at 500 volts alternating. The generators have six and eight poles respectively, giving frequencies of 20 and 26·6 per second. Connected to the shaft of each generator is an exciter, which in normal working gives about 30 amperes at 100 volts, but is capable of a considerable overload. A single 3-phase motor is coupled direct to the propeller shaft. This motor develops 500 shaft horse-power. The rotor is of the simple squirrel cage type, without any electrical or mechanical connections other than its rigid attachment to the propeller shaft. The stationary part of the motor has two separate windings for 30 and 40 poles respectively. These windings are mutually non-inductive, so that except for slight possible leakage of magnetism they exercise no influence whatever on one another and operate independently on the magnetic circuit of the motor. When these two windings are connected respectively to the appropriate generator the synchronous speed due to each is 80 revs. per minute, or actually about 78 revs. per minute when at full speed. By changing the connections the direc-



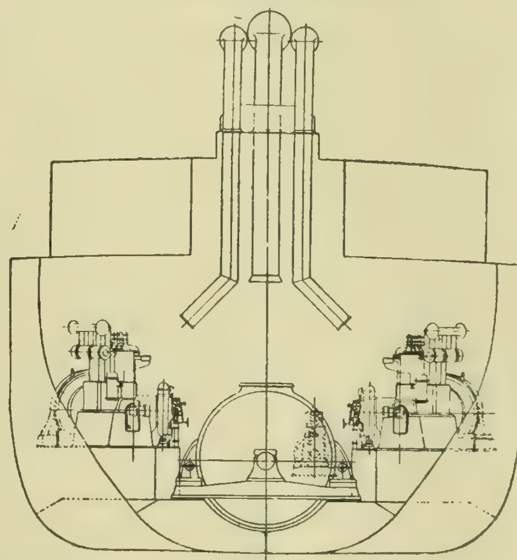
Sectional Elevation.



Section at Frame 13 looking aft.



Plan.



Section at Frame 13 looking forward.

FIG. 2.—VIEWS SHOWING ARRANGEMENT OF OIL-ELECTRIC PROPELLING MACHINERY.

tion of rotation is reversed, and by connecting the 40-pole winding of the motor to the 6-pole generator, the synchronous speed drops to 60 revs. per minute, or actually to 58 revs. per minute, giving about three-quarters of the full speed of the ship under this condition. One generator may be stopped and the other left running at full revolutions under governor control, and therefore at approximately its full economy, because the power required to drive the ship at three-quarter speed is about half of that required to drive it at full speed. If either of the generators is left attached to its own winding, the other generator being shut down either by intent or by accident, the ship is propelled by either engine at a little over half speed, the speed of the ship falling with the speed of rotation of the engine until an automatic adjustment of power and speed is reached. This occurs at about half speed.

The control gear is so simple as hardly to require any specific description. In the first instance, it is not proposed to operate the control from the bridge, but arrangements are made by which this can easily be done if required. There are five positions on the switch corresponding to the ordinary positions on the engine-room "telegraph." They are "full speed ahead," "half speed ahead," "stop," "half speed astern," and "full speed astern." Each position of the controller is definitely fixed by means of cams and roller, so that stopping at intermediate positions is prevented. For half speed, No. 1 generator is coupled to No. 2 winding of the motor, and No. 2 generator is running light or stopped. For full speed each generator is connected to its own winding in the motor respectively. The controlling gear provides for the interruption of the excitation of the generators while the switch is being moved from one step to another. This mode of operation renders the electric circuits "dead" while the switching over operation is being accomplished, and thus injurious sparking is avoided.

It will be seen that in this case the control gear is somewhat different from that of the "Jupiter." In the "Jupiter" the motors are provided with wound rotors in which resistances can be inserted for control of the rotor currents. In the present case there is no such control. The rotor current is allowed to rise to the value determined by the properties of the motor and the mechanical resistance imposed upon it by the shaft. The control of this current is limited to what is obtainable by control of the exciting field of the generator.

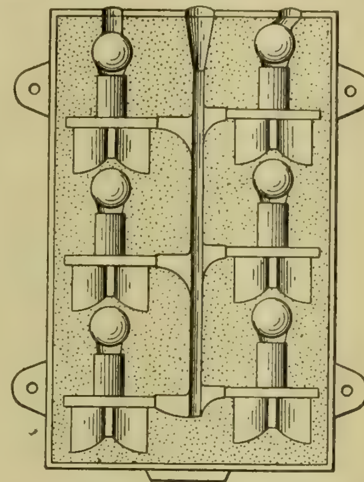
A long series of trials was carried out on the experimental vessel "Electric Arc," which was described by the writer in his communication last year, and on the data there obtained it has been found possible to design the equipment for this vessel, so that it is equal in simplicity to the smaller experimental equipment. This vessel has been purchased by the Montreal Transportation Company, Ltd., for service on the Canadian lakes. It is to be named "Tynemount." She is being built by Messrs. Swan, Hunter, & Wigham Richardson, Ltd., to the order of Messrs. the Electric Marine Propulsion Company, Ltd. The writer desires to acknowledge the valuable co-operation of Mr. John Reid, of Glasgow and Montreal, in the design of this vessel and her equipment.

Many other propositions are under consideration, but the policy of proceeding by successive steps towards the more important applications renders the rate of progress slow. The steps now made are from 50 to 500 and 5,000 h.p., so that not many more are required to demonstrate completely what are the capabilities of electric marine propulsion. It is to be hoped that this country may have the glory of making the next step. At present the credit of the largest equipment is with America.

Accident at a Railway Works.—A serious accident, involving injuries to six men, occurred on the 16th inst. in the Locomotive Works of the Caledonian Railway Company at St. Rollox, Glasgow. The direct cause of the accident is at present unknown, but it appears that while a number of moulders were making a casting in the brass foundry an explosion occurred, causing a quantity of molten brass, amounting to about 4 cwts., to scatter in all directions and to injure the majority of the men engaged in the operation.

MAKING AND CASTING NICKELENE OR SILVER METAL.

CONSIDERABLE difficulty is, says Mr. A. L. Goldsmith in "The Foundry," frequently experienced in casting the alloys of nickel and copper, known as nickelene, nickel silver, or silver metal, as the castings exhibit a strong tendency to run spongy or porous, and to also draw or shrink in the sharp corners, or wherever a heavy and light section are joined. In addition to the excessive contraction which causes the castings to break while being finished, the metal is hard and difficult to machine. The machining properties were improved by reducing the content of nickel, and the shrinkage and drawing were overcome by the use of suitable gates, shrink balls, and by regulating the pouring temperature of the metal. The accompanying illustration shows a half-mould containing several simple check discs for valves, and these castings were the source of much trouble, as they invariably contained a draw or shrinkage crack at the point of juncture of the stem and disc. This difficulty was overcome by placing a shrink ball on the end of the stem. Shrink balls must always be used in making castings from this alloy, and these should be of such a size that they will remain fluid after the casting has set, to supply metal for the shrinkage of the casting.



VERTICAL SECTION OF AN UPRIGHT MOULD OF VALVE CHECKS, SHOWING GATES AND SHRINK BALLS REQUIRED FOR CASTING NICKEL SILVER.

In addition to the use of shrink balls, it is advisable to avoid all sharp corners on either patterns or cores, as the hot metal has a tendency to cut or wash away the sand at such points, especially if green sand moulds are used. While wide, thin gates are better for brass, nickelene requires deep narrow gates, otherwise a draw or a shrinkage crack will result. The principal object in using nickelene or silver metal is to obtain castings of a uniform white colour, which will withstand repeated polishing without change of colour. This is not the case with plated goods, as the nickel is worn off by the friction of the polishing compound, and exposes the base metal underneath. To match tubing and nickel-plated ware, the following formula has been found most suitable by the writer:—

Copper	55lbs.
Nickel	12½lbs.
Zinc	20½lbs.
Lead	10lbs.
Tin	2lbs.

The nickel may be in either shot or disc form, and the alloy is made by first placing the copper and the nickel in the crucible together, keeping them well covered with charcoal or coke dust, and as soon as they are melted, the soft metals are added. The furnace then should be urged until the metal is so hot that it will bite into an iron bar, at which stage a piece of magnesium, about ¼in. square, or a small piece of aluminium should be added. The former deoxidiser is preferred. When adding it to the bath it is tied to an iron bar and plunged to the bottom of the crucible, the metal meanwhile being vigorously stirred. The crucible should then be removed from the furnace, skimmed, and poured. After the first mould is poured it will be well to take note whether the metal rises or swells in the sprue, and if it does, an additional piece of magnesium or aluminium should be added. However, care should be exercised to prevent using too large a quantity. In all cases where the sprues swell or rise in the centre, the castings should be scrapped, as they will be found defective when machined. In pouring this alloy the metal should be hot enough to smoke like yellow brass, otherwise the castings will be very liable to leak when tested. When poured at this temperature it was found that the tendency to shrink and crack was materially reduced.

THE COMMERCIAL ECONOMY OF TURBINE PUMPS.*

BY F. ZUR NEDDEN AND H. B. MAXWELL.

(*Continued from page 328*).

(5) **The Technical and the Commercial Efficiency.**—All that has been said in connection with the combined pressure and counterpressure diagram should prove that a man is wrong who thinks he is sure to get the best possible turbine pump for his purpose if he ties down the manufacturer as rigorously as possible to the efficiency guaranteed in the contract. On the contrary, it will often be directly against his best interests if the manufacturer chooses to give him exactly, and without any margin whatever, what was specified in the contract. The predominant factor for the valuation of a turbine pump is not the maximum efficiency obtained by it, but the suitability of its characteristic curve to the existing conditions of counter-pressure. This especially applies to the majority of high lift turbine pumps, viz., those driven direct by a 3-phase motor, *i.e.*, at constant speed.

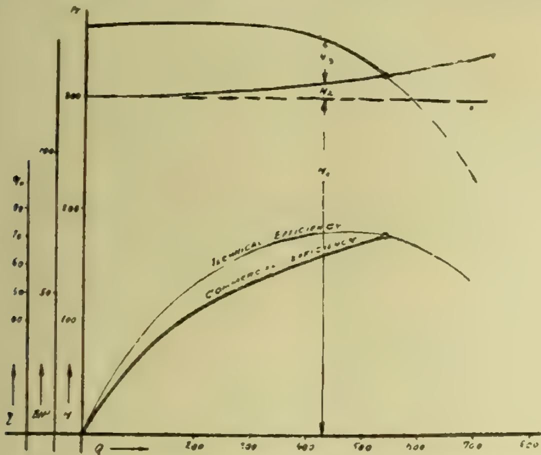
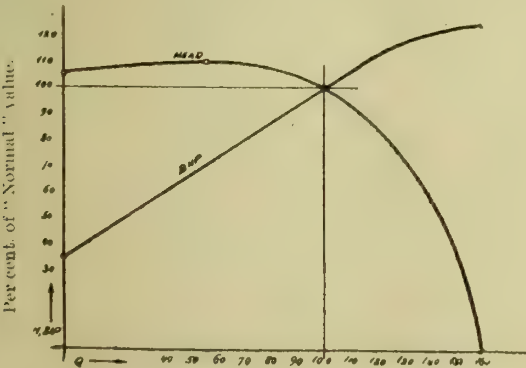


FIG. 15.—COMPARISON OF TECHNICAL AND COMMERCIAL EFFICIENCY.

The form of the characteristic curve, however, not only reflects on technical points, but, sometimes in a very heavy degree, also on the economical or commercial side of the question. This comes in as soon as the necessity arises to regulate the duty. This is very simply but very uneconomically done by throttling the regulating gate valve. An amount of counter-pressure equal to H_3, as per Fig. 13, has to be generated by throttling in order to get the pump to deliver just as much water as corresponds to a total counterpressure of $H_1 + H_2 + H_3$. The amount H_3 is absolutely wasted. Commercially, the efficiency curve as plotted in Fig. 13 is, therefore, of no great value, as it is based on the assumption that the pressure $H_1 + H_2 + H_3$ as indicated by the characteristic curve is useful pressure, whilst in reality only the part $H_1 + H_2$ is useful from the mine-owners' point of view. The ordinates of a curve of commercial efficiency have, therefore, to be reduced in the ratio of



Per cent. of "Normal" value.

FIG. 16.—STANDARD DIAGRAM OF NORMAL MODERN HIGH-LIFT TURBINE PUMP.

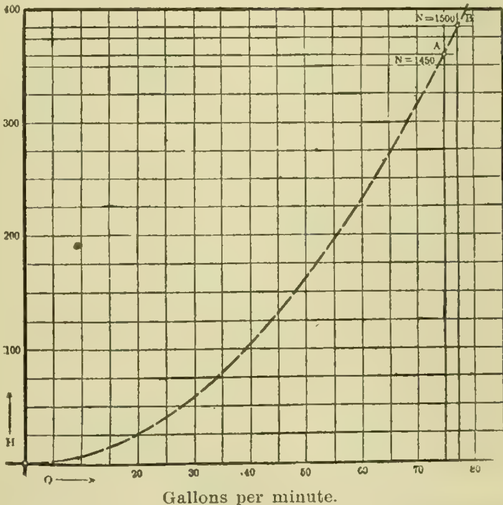
$$\frac{H_1 + H_2}{H_1 + H_2 + H_3}$$

and the result is shown in Fig. 15.

* Paper read before the South African Institution of Engineers.

It is evident how much depends on the shape of the characteristic curve before it meets with the counter-pressure curve. If the curve be flat, the excess H_3 of generated head above useful head will be small, and the regulating process is much more economical. The gap between technical and commercial efficiency is much smaller than shown in the present diagram. The latter, however, is better if great decrease in periodicity is to be provided for.

The importance of the form of the characteristic curve is evident. It would, however, not be right to try in every case to tie down manufacturers to obtaining or guaranteeing a special form of characteristic curve. In most cases manufacturers could not honestly give such a guarantee, especially with small or medium-size turbine pumps. Sometimes even two pumps made exactly alike in every respect have slight differences in their characteristics, which is easily conceivable when considering that a slight inexactitude in the moulding of an impeller has its effect multiplied by 1,500 or even 3,000 revs. per minute. But it must be emphasized that the above curves show that it is even more essential when ordering a turbine pump than when ordering a piston pump that the maker be supplied with every possible detail of the conditions under which the pumps will have to work. Success in the operation of a plant depends to a still higher degree on experience and the carefulness of the maker, with turbine pumps than with piston pumps. Many breakdowns of turbine pumps are due less to bad workmanship than to the want of experience on the part of the makers who built them. For the consulting or managing engineer, it will, in nine cases out of ten, be quite sufficient that he bases his economic considerations on a normal diagram, as shown by Fig. 16, as to-day the characteristic curves of the more prominent makes are already pretty much standardised. The authors have personally found the data contained in Fig. 16 to give a fair average of what may be expected from a normal, modern, standard, first-class high-lift turbine pump. Beyond using such standard curves it will, in the authors' opinion, be best to trust to the skill and experience of a conscientious maker to adapt the individual turbine pump to the existing conditions. After all, it is always possible to make the same slight alterations *in situ* which manufacturers make on the test bed, should it appear that too ample a margin has been left, or that an error has been made in determining the total counterpressure.



Gallons per minute.

FIG. 17.—VARIATION OF HEAD AND DELIVERY WITH VARYING SPEED.

The customer has, however, means at hand to free himself more or less from the influence of the characteristic curve by providing for speed regulation of some kind. If involuntary variations of speed seriously affect the reliability of the turbine pump plant, the economic effect of speed regulation, on the other hand, is most advantageous. Before giving concise examples as to the value of speed regulation we should regard the general effect of speed variation on our diagram. This can very simply be gathered from the following considerations:—

1. *Quantity.*—As an impeller takes in one definite quantity of water at each revolution, equal flow of water through

its channels presupposed, it is obvious that its output will vary in direct proportion to the number of revolutions.

2. *Head.*—As the relation between kinetic and static energy is:

$$H = \frac{c^2}{2g} \text{ wherein :}$$

H = head or pressure,

c = velocity,

g = acceleration due to gravity,

it follows that the head generated by a turbine pump is in proportion to the square of the speed. As all internal resistances which have to be subtracted from the theoretic head are dynamic ones, *i.e.*, they vary with the square of the speed, this law is proved to be absolutely right also in practice.

3. *Power.*—As the power required is the product of head and duty, and a constant, it follows that it must vary with the third power of the speed.

If we know point A, Fig. 17, to be a point of the characteristic curve for 1,450 revs. per minute, we can easily work out that the corresponding or "affine" point B on the characteristic curve for 1,500 revs. per minute lies where the abscissa

$$Q_B = Q_A \times \frac{1,500}{1,450}$$

meets the ordinate

$$H_B = H_A \times \frac{1,500^2}{1,450^2}$$

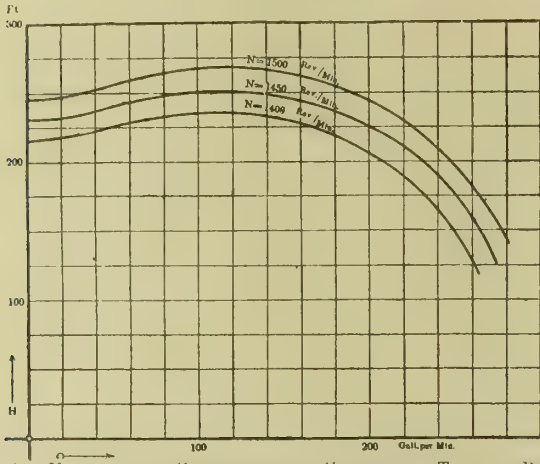


FIG. 18.—VARIATION OF CHARACTERISTIC CURVE OF A TURBINE PUMP WITH VARYING ROTARY SPEED.

In other words, when the speed varies the point A travels along a parabola as shown dotted in Fig. 17, which we call the parabola of affinity.

If the same calculation is carried through for different points, new curves, as per Fig. 18, are found for new speeds. The combination of such curves with one fixed counterpressure curve has already been shown by Fig. 13, and it is only necessary to replace 52, 50, and 48 cycles in that figure by 1,510, 1,450, and 1,390 revs. per minute in order to come to definite speeds.

Fig. 15 shows that the highest commercial efficiency is obtained at the point of intersection between pressure and counterpressure curve. The highest possible economy will, therefore, be secured by regulating the duty along the counterpressure curve, *i.e.*, from P_1 viâ P to P_2. This is done by regulating the speed. It should be noted that the duty then varies in a much higher percentage than the speed, as the pressure and the counterpressure curves intersect at a rather acute angle. This is favourable, as it implies only a small range of speed regulation for a considerable range of duty regulation. The efficiency of the driving motor will, therefore, remain practically constant, and it is quite correct to arrive at an opinion about the economic effect of such duty regulation by speed regulation through solely comparing the change effected in the commercial efficiency of the pump.

Fig. 19 shows the efficiency diagrams for the three characteristic curves as per Fig. 13. They are very simply obtained by noting that, within a margin of speed variation of about 5 per cent. above or below normal, the efficiency remains practically constant along each parabola of affinity, or for all relative points such as points A and B in Fig. 17. This diagram enables us, by picking out the efficiencies corresponding to points P, P_1, and P_2 (which are commercial efficiencies in the sense defined before) to plot the principal curve in Fig. 20. This diagram permits a direct comparison with Fig. 15, and clearly shows the exact amount of advantage derived from regulating the speed.

It will now depend on the conditions of the particular job in question whether these advantages must be considered large enough to accept the complication always incurred by regulat-

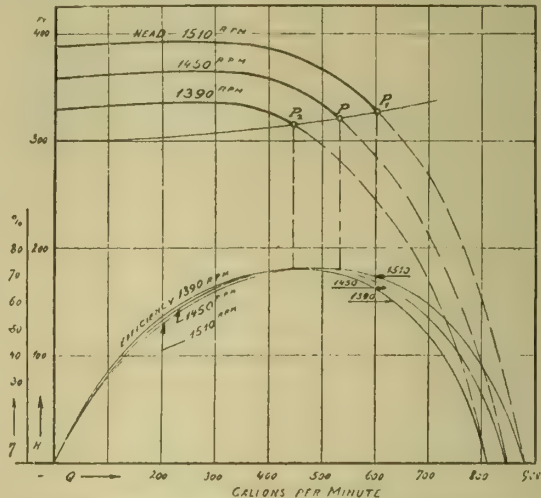


FIG. 19. SPEED DIAGRAM ON WHICH FIG. 20 IS BASED.

ing devices, except, perhaps, when the pump be direct-coupled to a direct-current motor, where it is very trifling. By capitalising the saving in efficiency it can easily be found whether it would pay to go to the extra expense of buying a variable-speed 3-phase motor, provided the pump station be dry enough to avoid collector troubles. In some instances it is quite a good solution to couple the pump to a countershaft driven by belt off an ordinary 3-phase motor, provided there were room enough for the belt drive. The countershaft or motor pulley could then be altered in diameter to suit various conditions. If the pump station had to be enlarged to provide space enough for the belt drive, the cost of making the station larger would, in most cases, absorb the capitalised saving in commercial efficiency.

It should of course be emphasized that the conclusions to be drawn from the above diagrams must in no way be generalised, and in order to prevent any misinterpretation it is the author's purpose to show another typical case of turbine pump work where the conclusions deduced from the combined diagrams are quite different. Main drainage generally gives a type of counterpressure diagram consisting mainly of static pressure. The aspect completely varies as soon as dynamic resistances form the principal constituents of the counterpressure, as they often do with waterworks. Let us consider a case where about half-a-million gallons per 24 hours had to

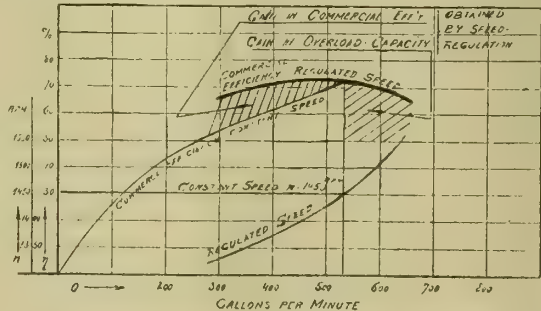


FIG. 20. ECONOMIC EFFECT OF SPEED VARIATION.

be pressed through a 6in. pipe line four miles long from a spring to a reservoir, the total level difference to be overcome being 45ft. in the rainy seasons and 55ft. maximum during a dry summer. From the outset it is clear that a turbine pump coupled direct to a 3-phase motor must be a suitable machine for the purpose, as it represents nothing else but a means of elevating the level of the spring to such a height that its water flows into the city reservoir by itself. By working out the combined pressure and counterpressure diagram this simple reasoning is, in a way, verified, but at the same time grave dis-

advantages are detected. According to the well-known formula—

$$h = \frac{k \times l \times v^2}{64 \times 4 \times d}$$

where k = 0·026 the coefficient of pipe friction
l = length of pipe in feet
v = velocity of water in feet per second
d = diameter of pipe in feet

the resistance h of the pipe line works out at 107ft. for a flow equivalent to a delivery of 500,000 galls. per day. A coating about ⅛in. thick as formed in every pipe after a certain time would, by altering v and d in the above formula, add another 10ft. to that resistance, and as the frictional resistance of the coating is different from that of the bare pipe an increase of, say, 5 per cent. in the coefficient k must be taken into account. This would bring the total pipe resistance for 500,000 galls. per day up to something like 122ft. The pump will therefore be ordered for a pressure $P = 177$ft. when delivering 500,000 galls. per day, and running at a synchronous speed of, say, 1,500 revs. per minute. The maker will probably supply a turbine pump pressing up to about 184ft., giving it a 5 per cent. margin. The pressure curve of that pump might be in accordance with the general standard curve, Fig. 16. The counterpressure curves can now easily be traced, and it will be noted from Fig. 21 that by their intersecting the pressure curve at an obtuse angle the influence of their moving, through the various reasons mentioned before, from point P to point P_3 is extremely small as regards duty

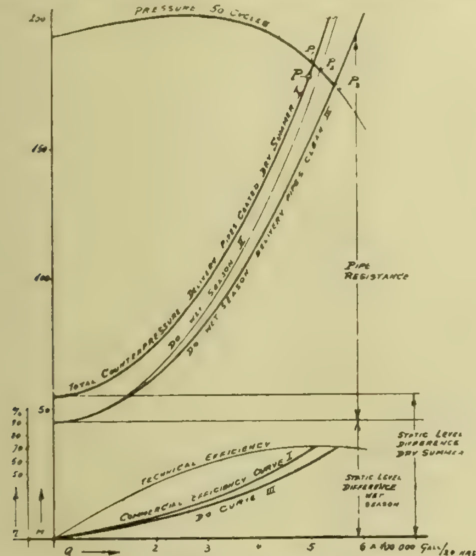


FIG. 21.—COMBINED PRESSURE AND COUNTERPRESSURE DIAGRAM FOR WATERWORKS PUMPING PLANT.

and efficiency. In addition no great fear need be entertained as to the failing of the pump through change of periodicity as it cannot "snap off," nor will the load vary too much. The greatest drawback of the plant is to be found in its being rigidly bound to a minimum range of duty. Neither is it at all possible to get a greater duty out of the pump than 9 to 10 per cent. more than that specified (point P_3), nor will it be advisable to throttle the duty down by means of the regulating valve, as the commercial efficiency quickly falls off in consequence of the steep incline of the counterpressure curve in comparison with the flat pressure curve.

For conditions like these, *i.e.*, if the dynamic resistances form the greater portion of the counterpressure, the turbine pump may only be driven at constant speed if it is not necessary for it to handle varying quantities. As soon as quantity regulation becomes important, it must be provided for by means of regulating the speed. Whilst with a counterpressure consisting mainly of static head 1 per cent. of speed variation is equivalent to a 3 to 6 per cent., or even higher percentage, of change in duty, the effect of speed variation on counterpressure systems with large dynamic resistances is only about one to one. A particularly large range of speed regulation is, therefore, required, which is generally most economically obtained by direct coupling the pump to a steam turbine.

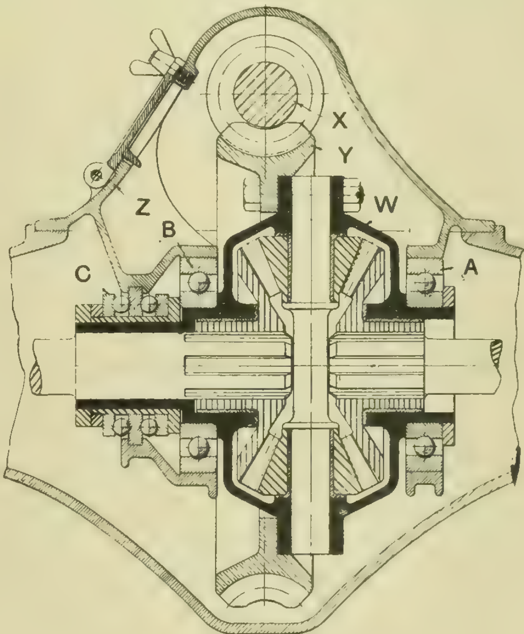
The number of examples could be increased by many others, but it will be better to devote the remainder of the paper to discussing some other factors influencing economy besides the shape of pressure and counterpressure curves. The principal of these is the influence of wear and tear on the economy. Of course, wear can never be quite avoided, but it should be emphatically stated that users of turbine pumps can assist in at least as high a degree as can the makers in minimising wear and tear and their consequences.

The effects of wear and tear on the efficiency of a turbine pump consist almost exclusively in the leakage through worn-out bushes. The possible maximum of leakage is not the same in all makes, and the principal reason why the efficiency of one pump will decrease sooner than that of another pump working under similar conditions, especially if the number of stages is the same in each case, is to be found in the different designs for balancing the axial thrust. As one of the authors dealt more broadly with the practical side of this question in the "Engineering Magazine," 1910,* we will only deal with the economic side of the question.

(To be continued.)

WORM GEARING FOR MOTOR-CARS.

THE usual method of mounting a worm wheel midway between its bearings on the rear axles of worm-driven motor road vehicles, although presenting a symmetrical design, throws an unequal load on the journals due to the side thrust on the worm wheel caused by the angularity of the thread. These unequal loads can only be counteracted by placing the worm wheel out of centre, the exact distance being dependent upon the angle of inclination of the worm thread and the pressure angle of the teeth. Where the worm wheel is so placed out of centre the design presents an unsymmetrical appearance, but if, as shown in the accompanying illustration, a double ball thrust is arranged on the side of the journal remote from the direction of the side thrust on the wheel, then the correct



WORM GEARING FOR MOTOR-CARS.

position of the wheel to give equal loads on the bearings will be approximately midway between the two extreme points of the unit, thus giving all the advantages of increased efficiency together with a neat and symmetrical appearance. In the arrangement illustrated, the invention of Messrs. D. Brown & Sons, Ltd., Park Gear Works, Lockwood, Huddersfield, the worm wheel is unsymmetrically placed between its journals. Referring to the illustration, X is a worm which transmits motion to the worm wheel Y mounted on the differential casing W which contains the usual differential gear, and is set out of centre. The differential gearing is mounted on two journal bearings A and B carried by the case Z. In this arrangement of gearing an equal load is obtained on each bearing. A double-acting thrust bearing C is located on one side of the worm or spiral gear wheel whereby a symmetrical design is obtained and the efficiency of the gearing increased, the thrust in both directions being taken up by this bearing.

* "Engineering Magazine," May 1910—"Design, Construction, and Operation of High-lift Centrifugal Pumps," by Mr. F. Zur Nedden

NOMENCLATURE OF MICROSCOPIC SUBSTANCES AND STRUCTURES OF STEEL AND CAST IRON.*

I.—GENERAL PLAN.

WE first enumerate the substances of such importance as to warrant it, indicating roughly their constitution, and then define and describe certain of them.

The conditions which we meet are (1) that we need definitions on which all can agree; and this implies that they must be free from all contentious matter and be based on what all admit to be true. (2) That the reader must needs know the current theories as to the constitution of these substances, and these theories are necessarily contentious. We meet these conditions by the plan of giving (1) the name which we recommend for general use, followed immediately in parentheses by the other names used widely enough to justify recording them; (2) the definition proper, based on an undisputed quality, *e.g.*, that of austenite, which we base on its being an iron-carbon solid solution, purposely omitting all reference to the precise nature of solvent and solute; and (3) constitution, &c., in which we give the current theories as to the nature of solvent and solute and appropriate descriptive matter.

The distinction between these three parts should be understood: (1) the names actually used are matter of record and indisputable; (2) the definitions are matters of convention or treaty, binding on the contracting parties, though subject to denouncement, preferably based on some determinable property of the thing defined as distinguished from any theory as to its nature, or if necessarily based on any theory it should be a theory which is universally accepted. It is a matter purely of convention and general convenience what individual property of the thing defined shall form the basis of the definition. The name and the definition should endure permanently, except in the case of a definition based on an accepted theory, which must be changed if the theory should later be disproved. (3) Theories and descriptions are not matters of agreement or convention, but dependent on observation, and therefore always subject to be changed by new discoveries. They are temporary in their nature, as distinguished from the names and definitions which should be fixed, at least relatively.

This case of austenite illustrates the advantage of non-indicative names. The names which we propose to displace, "gamma iron" and "mixed crystals," imply definite theories as to the nature of austenite, and hence might have to be abandoned in case those theories were later disproved. The name "austenite" implies nothing, like mineralogical names in general, and hence is stable in itself. Our infant branch of science may well learn from its elder sister, which has tried and proved the advantage of this non-indicative naming.

In those cases in which a name has been used in more than one sense we advise the retention of one and the abandonment of the others, having obtained the consent of the proposers of such names for their abandonment.

Many whose judgment we respect object to our including certain of the less used names, *e.g.*, from "i" to "n" in our list, holding them either to be confusing or to be needless. It is true that several names (hardenite, martensite, sorbite, &c.) have been used with various meanings, and hence confusingly, in spite of which most of them should be retained, each with a single sharp-cut definition, because they are so useful.

As regards the alleged needlessness of certain names, it is for each writer to decide whether he does or does not need names with nice shades of meaning, such as osmondite and troosto-sorbite. Those who look only at the general outlines and not at the details have no right to forbid the workers in detail from having and using words fitting their work; nor have those whose needs are satisfied by the three primary colours a right to forbid painters, dyers, weavers, and others from naming the many shades with which they are concerned. Like the lexicographer, we must serve the reader by explaining those words which he will meet, whether we individually use or condemn them. We feel that we have exhausted our powers in cautioning writers that certain words are rare and not likely to be understood by most readers, or are improper for any reason, and in urging the complete abandonment of those withdrawn by their proposers.

Needless words will die a natural death; needed ones we cannot kill. The good we might do in hastening the death of the moribund by omitting them from this report is less than the good we do by teaching their meaning to those who will meet them in ante-mortem print. These readers have rights. We serve no class, but the whole.

II.—LIST OF MICROSCOPIC SUBSTANCES.

The microscopic substances here described consist of:—

(1) *Metarals*, true phases, like the minerals of nature. These are either elements, definite chemical compounds, or solid solutions, and hence consisting of definite substances in varying proportions. These include austenite, ferrite, cementite, and graphite.

(2) *Aggregates*, like the petrographic entities as distinguished from the true minerals. These mixtures may be in definite proportions, *i.e.*, eutectic, or eutectoid mixtures (ledeburite, pearlite, steadite), or in indefinite proportions (troostite, sorbite). Those aggregates which are important for any reason are here described.

(Many true minerals, such as mica, felspar, and hornblende, are divisible into several different species so that these true mineral names may be either generic or specific. These genera and species are definite chemical compounds, in which one element may replace another. Other minerals, such as obsidian, are solid solutions in varying proportions, and in these also one element may replace another. Metarals like minerals differ from aggregates in being severally chemically homogeneous.)

These two classes may be cross classified into:—

(A) The iron-carbon series, which come into being in cooling and heating.

(B) The important impurities manganese sulphide, ferrous sulphide, slag, &c.

(C) Other substances.

The most prominent members of the iron-carbon series are:—

1.—Molten iron, metaral, molten solution, but hardly a microscopic constituent.

2.—The components which form in its solidification:—

(*a*) Austenite, solid solution of carbon or iron carbide in iron, metaral;

(*b*) Cementite, definite metaral, Fe_3C;

(*c*) Graphite, definite metaral, C.

3.—The transition substances which form through the transformation of austenite during cooling:—

(*d*) Martensite, metaral of variable constitution; its nature is in dispute;

(*e*) Troostite, indefinite aggregate, uncoagulated mixture;

(*f*) Sorbite, indefinite aggregate, chiefly uncoagulated pearlite plus ferrite or cementite.

4.—Products† of the transformation of austenite:—

(*g*) Ferrite;

(*h*) Pearlite.

This transformation may also yield cementite and graphite as end products in addition to those under (*b*) and (*c*).

In addition to the above, the names of which are universally recognised and in general use, the following names have been used more or less:—

(*i*) Ledeburite (Wüst), definite aggregate, the austenite-cementite eutectic;

(*j*) Ferronite (Benedicks), hypothetical definite metaral, beta iron containing about 0·27 per cent. of carbon;

(*k*) Steadite (Sauveur), definite aggregate, the iron-phosphorus eutectic (rare);

And three transition stages in the transformation of austenite, viz.:—

(*l*) Hardenite (Arnold), collective name for the austenite and martensite of eutectoid composition;

(*m*) Osmondite (Heyn), boundary stage between troostite and sorbite;

(*n*) Troosto-sorbite (Kourbatoff), indefinite aggregate, the

* Report of committee on "The Nomenclature of Microscopic Substances and Structures of Steel and Cast Iron," presented to the sixth congress of the International Association for Testing Materials, in New York, September, 1912. It was prepared by the chairman, H. N. Howe, and the secretary, A. Sauveur, and was supported unanimously by the committee and adopted by the congress. In addition to Prof. Howe and Prof. Sauveur the committee was composed of the following: F. Osmond, Paris; Dr. H. C. H. Carpenter, Manchester; Prof. W. Campbell, New York; Prof. C. Benedicks, Stockholm; Prof. F. Wüst, Aachen; Prof. A. Stansfield, Montreal; Dr. J. E. Stead, Middlesbrough; Prof. L. Guillet, Paris; Prof. E. Heyn, Berlin-Lichterfelde; Dr. W. Rosenhain, Teddington, England.

† In hypo-eutectoid steels these habitually play the part of end products, though according to the belief of most the true end of the transformation is not reached till the whole has changed into a conglomerate of ferrite plus graphite.

troostite and the sorbite which lie near the boundary which separates these two aggregates (obsolescent).

III.—DEFINITIONS AND DESCRIPTIONS.

Carbon iron equilibrium diagram, Fig. 1. Under the several substances about to be described an indication will be given of the parts of the carbon iron equilibrium diagram, Fig. 1, to which they severally correspond.

AUSTENITE.

Osmond (Fr. Austénite, Ger. Austenit, called also mixed crystals and gamma iron. Up to the year 1900 often called martensite, and wrongly sometimes still so called). Metaral of variable composition.

Definition.—The iron-carbon solid solution as it exists above the transformation range or as preserved with but moderate transformation at lower temperatures, *e.g.*, by rapid cooling, or by the presence of retarding elements (Mn, Ni, &c.), as in 12 per cent. manganese steel and 25 per cent. nickel steel.

Constitution and Composition.—A solid solution of carbon or iron carbide (probably Fe_3C) and gamma iron, normally stable only above the line PSK of the carbon iron diagram. It may have any carbon content up to saturation as shown by the line SE, viz., about 0·90 per cent. at S (about 725° C.) to 17 per cent. at E (about 1,130°). The theory that the iron and the carbide or carbon, instead of being dissolved in each other, are dissolved in a third substance, the solution of eutectic composition ($Fe_{24}C$ called hardenite) is not in accord with the generally accepted theory of the constitution of solutions, and is not entertained widely or by any member of this committee.

Crystallisation.—Isometric. The idiomorphic vug crystals are octahedra much elongated by parallel growth. The etched sections show much twinning. (Osmund and most authorities.) Le Chatelier believes it to be rhombohedral. Cleavage octahedral.

Varieties and Genesis.—(1) Primary austenite formed in the solidification of carbon steel and hypo-eutectic cast iron. (2) Eutectic austenite, interstratified with eutectic cementite, making up the eutectic formed at the end of the solidification of steel containing more than about 1·7 per cent. of carbon, and of all cast iron.

Equilibrium.—It is normal and in equilibrium in Region 4, and also associated with beta iron in Region 6, with alpha iron in Region 7, and with cementite in Region 5. It should normally transform into pearlite with either ferrite or cementite on cooling past A1 into Region 8.

Transformation.—In cooling slowly through the transformation range, Ar_3—Ar_1, austenite shifts its carbon content spontaneously through generating pro-eutectoid ferrite or cementite, to the eutectoid ratio, about 0·90 per cent., and then transforms with increase of volume at Ar_1 into pearlite, q. v., with which the ejected ferrite or cementite remains mixed. Rapid cooling and the presence of carbon, manganese, and nickel obstruct this transformation, (1) retarding it, and (2) lowering the temperature at which it actually occurs, and in addition (3) manganese and nickel lower the temperature at which in equilibrium it is due. Hence, by combining these four obstructing agents in proper proportions the transformation may be arrested at any of the intermediate stages, martensite, troostite, or sorbite*, q. v., and if arrested in an earlier stage, it can be brought to any later desired stage by a regulated reheating or "tempering." For instance, though a very rapid cooling in the absence of the three obstructing elements checks the transformation but little and only temporarily, yet, if aided by the presence of a little carbon, it arrests the transformation wholly in the martensite stage; and in the presence of about 1·50 per cent. of carbon such cooling retains about half the austenite so little altered that it is "considerably" softer than the usually darker needles of the surrounding martensite, with which it contrasts sharply. Again, either (*a*) about 12 per cent. of manganese plus 1 per cent. of carbon, or (*b*) 25 per cent. of nickel, lower and obstruct the transformation to such a degree that austenite persists in the cold apparently unaltered, even through a slow cooling. (Hadfield's manganese steel and 25 per cent. nickel steel, manganiferous and nickeliferous austenite respectively.)

Occurrence.—When alone (12 per cent. manganese and 25 per cent. nickel steel and Maurer's 2 per cent. carbon plus 2 per cent. manganese austenite) polyhedra, often coarse, much twinned at least in the presence of martensite, and readily developing slip bands. In hardened high-carbon steel it forms a ground mass pierced by zig-zag needles and lances of martensite.

Etching.—All the common reagents darken it much more than cementite, less than troostite or sorbite, and usually less, though sometimes more, than martensite, which is recognised by its zig-zag shape and needle structure. With ferrite and pearlite it is never associated.

Physical Properties.—Maurer's austenite of 2 per cent. manganese plus 2 per cent. carbon is but little harder than soft iron, and 25 per cent. nickel steel and Hadfield's manganese steel are but moderately hard. Yet, as usually, preserved in hardened high carbon steel, the hardness of austenite does not fall very far short of that of the accompanying martensite, probably because partly transformed in cooling. (Osmond's words are that it is "considerably" softer than that martensite.)

Specific magnetism very slight unless perhaps in intense fields. In Hadfield's manganese steel and 25 per cent. nickel steel, very ductile.

CEMENTITE.

(Sorby "intensely hard compound," Ger. cementit, Fr. cémentite, Arnold, crystallised normal carbide.) Definite metaral.

Definition.—Tri-ferrous carbide Fe_3C. The name is extended by some writers so as to include tri-carbides, in

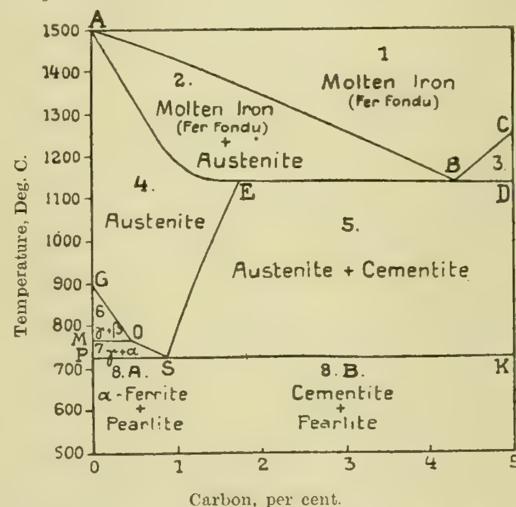


FIG. 1.—A1, the line PSK is often called "A1." A3, the line GOS is often called "A3," and this name is sometimes applied to the line SE.

which part of the iron is replaced by manganese or other elements. Such carbides may be called "manganiferous cementite," &c.

(2) *Occurrence.*—(*a*) Pearlitic, as a component of pearlite, q. v.; (*b*) eutectic; (*c*) primary or pro-eutectic; (*d*) pro-eutectoid; (*e*) liberated by the splitting up of the eutectic or of pearlite; and (*f*) uncoagulated in sorbite, troostite, and perhaps martensite; (*c*), (*d*), and (*e*) are grouped together as "free" or "massive."

Primary cementite is generated in cooling through Region 3; eutectic cementite on cooling past the line EBD; pro-eutectoid cementite in cooling through Region 5; pearlite cementite on cooling past the line PSK, or A1. Though the several varieties of cementite are generally held to be all metastable, tending to break up into graphite plus either austenite above A1 or ferrite below A1, yet they have a considerable and often great degree of persistence. The graphitising tendency is completely checked in the cold, but increases with the temperature, and with the proportion of carbon and of silicon present, and is opposed by the presence of manganese.

(3) *Crystallisation.*—Orthorhombic, in plates.

(4) *Structure.*—(*a*) Pearlitic, in parallel unintersecting plates alternating with plates of ferrite; (*b*) eutectic, plates

* Though the transformation can be arrested in such a way as to leave the whole of the steel in the condition of martensite, it is doubted by some whether it can be so arrested as to leave the whole of it in any of the other transition stages. Troostite and sorbite caused by such arrest are habitually mixed, troostite with martensite or sorbite or both, and sorbite with pearlite or troostite or both.

forming a network filled with a fine conglomerate of pearlite with or without pro-eutectoid cementite; (*c*) primary, in manganiferous white cast iron, &c., in rhombohedral plates; (*d*) in hyper-eutectoid steel, pro-eutectoid cementite forms primarily a network enclosing meshes of pearlite, through which cementite plates or spines sometimes shoot if the network is coarse; (*e*) cementite liberated from pearlite merges with any neighbouring cementite; (*f*) the structure of uncoagulated cementite cannot be made out. On long heating the pro-eutectoid and pearlitic cementite spheroidise slowly, and neighbouring particles merge; (*g*) in white irons rich in phosphorus in flat plates embedded in iron-carbon-phosphorus eutectic.

(5) *Etching, &c.*—After polishing stands in relief brilliant white after etching with dilute hydrochloric or picric acid, darkened by boiling with solution of sodium picrate in excess of sodium hydrate.

(6) *Physical Properties.*—Hardest component of steel. Hardness = 6 of Mohs scale. Scratches glass and felspar but not quartz: very brittle. Specific magnetism about two-thirds that of pure iron.

MARTENSITE.

(Fr. Martensite, Ger. Martensit), Metaral. Its nature is in dispute.

Definition.—The early stage in the transformation of austenite characterised by needle structure and great hardness, as in hardened high-carbon steel.

Constitution.—I. (Osmond and others), a solid solution like austenite, q. v., except that the iron is partly beta, whence its hardness, and partly alpha, whence its magnetism in mild fields. II. (Le Chatelier) the same except that its iron is essentially alpha, and the hardness due to the state of solid solution. III. (Arnold) a special structural condition of his "hardenite" (austenite); not widely held. IV. A solid solution in gamma iron. V. (Benedicks.) The same as I., except that the iron is wholly beta, and that beta iron consists of alpha iron containing a definite quantity of gamma iron in solution.

Equilibrium.—It is not in equilibrium in any part of the diagram, but represents a metastable condition in which the metal is caught during rapid cooling, in transit between the austenite condition stable above the line A1 and the condition of ferrite plus cementite into which the steel habitually passes on cooling slowly past the line A1.

Occurrence.—The chief constituent of hardened carbon tool steels, and of medium nickel and manganese steels. In still less fully-transformed steels (1·50 per cent. carbon steel rapidly quenched, &c.), it is associated with austenite; in more fully transformed ones (lower carbon steels hardened, high carbon steels oil hardened, or water hardened and slightly tempered, or hardened thick pieces even of high carbon steel) it is associated with troostite, and with some pro-eutectoid ferrite or cementite, q. v., in hypo and hyper-eutectoid steels respectively. In tempering it first changes into troostite; at 350°—400° it passes through the stage of osmondite; at higher temperatures it changes into sorbite; at 700° into granular pearlite. On heating into the transformation range this changes into austenite, which on cooling again yields lamellar pearlite.

Characteristic specimens are had by quenching bars 1 cm. square of eutectoid steel, *i.e.*, steel containing about 0·9 per cent. of carbon in cold water from 800° C. (1,472° Fah.).

Structure.—When alone, habitually in flat plates made up of intersecting needles parallel to the sides of a triangle. When mixed with austenite, zig-zag needles, lances, and shafts.

If produced by quenching after heating to 735° C., it consists of minute crystallites resembling the globulites of Vogelsang, which are rarely arranged in triangular order. At times so fine as to suggest being amorphous.

Etching.—With picric acid, iodine, or very dilute nitric acid etches usually darker than austenite, but sometimes lighter, always darker than ferrite and cementite, but always lighter than troostite.

FERRITE.

(Fr. Ferrite, Ger. Ferrit). Definite metaral.

(1) *Definition.*—Free alpha iron.

(2) *Composition.*—Nearly pure iron. It may contain a little phosphorus and silicon, but its carbon content, if any, is always small, at the most not more than 0·05 per cent., and perhaps never as much as 0·02 per cent.

(3) *Occurrence.*—(*a*) Pearlitic as a component of pearlite, q. v.; (*b*) pro-eutectoid ferrite generates in slow cooling through the transformation range; (*c*) that segregated from pearlite, *i.e.*, set free by the splitting up of pearlite, especially in low carbon steel; (*d*) uncoagulated as in sorbite and probably troostite; (*b*) and (*c*) are classed together as free or massive.

Thus ferrite is normal and stable in Regions 7 and 8.

(4) *Crystallisation*, isometric, in cubes or octahedra.

(5) *Structure.*—(*a*) Pearlitic ferrite, unintersecting parallel plates alternating with plates of cementite; (*b*) pro-eutectoid ferrite in low-carbon steel forms irregular polygons, each with uniform internal orientation. In higher carbon steel, after moderately slow cooling, especially in the presence of manganese, it forms a network enclosing meshes of pearlite. In slower cooling this network is replaced by irregular grains separated by pearlite; (*c*) the ferrite set free by the splitting up of pearlite merges with the pro-eutectoid ferrite, if any; (*d*) the structure of the ferrite in sorbite, &c., cannot be made out.

(6) *Etching.*—Dilute alcoholic nitric or picric acid on light etching leaves the ferrite grains white with junctions which look dark. Deeper etching, by Heyn's reagent or its equivalent, reveals the different orientation of the crystals or grains, (*a*) as square figures parallel to the direction of the etched surface; (*b*) as plates which dip at varying angles and becomes dark or bright when the specimen is rotated under oblique illumination. Still deeper etching reveals the component tubes (etching figures, Atzfiguren), at least if the surface is nearly parallel to the cube faces.

(7) *Physical Properties.*—Soft; relatively weak (tenacity about 40,000lbs. per square inch); very ductile; strongly ferro-magnetic; coercitive force very small.

Grain Size.—For important purposes (1) etch deeply enough, *e.g.*, with copper-ammonium chloride, to reveal clearly the junctions of the grains; (2) count on a photograph of small magnification the number of grains in a measured field so drawn as to exclude fragments of grains; after (3) determining the true grain boundaries by examination under high powers (Heyn's method). Deep nitric acid etching is inaccurate, because an apparent grain boundary may contain several grains.

OSMONDITE.

(Fr. Osmondite, Ger. Osmondit.)

Definition.—That stage in the transformation of austenite at which the solubility in dilute sulphuric acid reaches its maximum rapidity. Arbitrarily taken as the boundary between troostite and sorbite.

Earlier Definition.—Defined by the Fifth Congress as having the "maximum solubility in acids and by a maximum colouration under the action of acid metallographic reagents." The present definition is confined to maximum rapidity of dissolving, because we do not yet know that this in all cases co-exists with the maximum depth of colouration, and in any case in which these two should not co-exist, the old definition does not decide which is true osmondite.

Constitution.—The following hypotheses have been suggested, none of which has firm experimental foundation: (1) A solid solution of carbon or an iron carbide in alpha iron. (2) The colloidal system of Benedicks in its purity, troostite being this system while forming at the expense of martensite, and sorbite being this system coagulating and passing into pearlite. (3) The stage of maximum purity of amorphous alpha iron on the way to crystallising into ferrite.

Occurrence.—Hardened carbon steel of about 1 per cent. of carbon when reheated (tempered) to 350° to 400° C. passes through the stage of troostite to that of osmondite, and on higher heating to that of sorbite. What variation, if any, from this temperature is needed to bring hardened steel of other carbon content to the osmondite stage is not known. In that it represents a true boundary state between troostite and sorbite it differs in meaning from troostosorbite, which embraces both the troostite and the sorbite which lie near this boundary. Indeed, osmondite has sometimes been used in

this looser sense. Writers are cautioned that, however useful these terms may prove for making these nice discriminations, they are not likely to be familiar to general readers.

Etching.—According to Heyn, it differs from troostite and sorbite in being that stage in tempering which colours darkest on etching with alcoholic hydrochloric acid.

The present definition and description of osmondite should displace previous ones, because they have the express approval of Prof. Heyn, the proposer of the name, and M. Osmond himself.

FERRONITE.

(Fr. Ferronite, Ger. Ferronit) (Benedicks) hypothetical definite metaral.

Definition.—Solid solution of about 0·27 per cent. of carbon in beta iron.

Occurrence (hypothetical).—In slowly cooled steels and cast iron containing 0·50 per cent. of combined carbon or more, that which is generally believed to be ferrite, whether pearlitic or free, is supposed by Benedicks to be ferronite.

HARDENITE.

(Fr. Hardenite, Ger. Hardenit.)

Definition.—Collective name for austenite and martensite of eutectoid composition. It includes such steel (1) when above the transformation range, and (2) when hardened by rapid cooling.

Observations.—On the generally accepted theory that austenite is a solid solution of carbon or an iron carbide in iron, hardenite is the solution of the lowest transformation temperature, *i.e.*, the eutectoid. The theory that instead it is a definite chemical compound, $Fe_{24}C$, is considered under austenite. Its proposer includes under hardenite both eutectoid (0·90 per cent. carbon) austenite when above the transformation range, and the martensite into which that austenite shifts in rapid cooling (hardening).

Other Meanings.—Originally (Howe, 1888) collective name for austenite and martensite of any composition in carbon steel. Osmond (1897), austenite saturated with carbon. Both these meanings are withdrawn by their proposers.

PEARLITE.

(Sorby's "pearly constituent." At first written "pearlyte." Fr. Perlite, Ger. Perlit.) Aggregate.

Definition.—The iron-carbon eutectoid, consisting of alternate masses of ferrite and cementite.

Constitution and Composition.—A conglomerate of about 6 parts of ferrite to 1 of cementite. When pure, contains about 0·90 per cent. of carbon, 99·10 per cent. of iron.

Occurrence.—Results from the completion of the transformation of austenite brought spontaneously to the eutectoid carbon-content, and hence occurs in all carbon steels and cast iron containing combined carbon and cooled slowly through the transformation range, or held at temperatures in or but slightly below that range, long enough to enable the ferrite and cementite to coagulate into a mass microscopically resoluble. Hence it is the normal constituent in Region 8. Its ferrite is stable, but its cementite is metastable and tends to transform into ferrite and graphite.

Varieties and Structure.—Because pearlite is formed by the coagulation of the ferrite and cementite initially formed as the irresoluble emulsion, sorbite (Arnold's sorbitic pearlite), there are the indefinitely bounded stages of sorbitic pearlite (Arnold's normal pearlite), *i.e.*, barely resoluble pearlite, in the border land between sorbite and laminated pearlite; granular pearlite, in which the cementite forms fine globules in a matrix of ferrite; and laminated or lamellar pearlite, consisting of fine, clearly defined, non-interesecting, parallel lamellae alternately of ferrite and cementite. The name granular pearlite was first used by Sauveur to represent what is now called sorbite. This meaning has been withdrawn.

An objection to Arnold's name "normal pearlite" is that it is likely to mislead. "Normal" here apparently refers to arising under normal conditions of cooling, but (1) it rather suggests structure normal for pearlite, which surely is the lamination characteristic of eutectics in general, and (2) the general reader has no clue as to what conditions of cooling are here called normal. Many readers are not manufacturers, and even in manufacture itself air cooling is normal for one branch and extremely slow furnace cooling for another. Arnold calls troostite "troostitic pearlite" and sorbite "sorbitic pearlite." This is contrary to general usage, which restricts pearlite to microscopically resoluble masses.

Etching.—After etching with dilute alcoholic nitric or picric acid it is darker than ferrite or cementite, but lighter than sorbite and troostite. A magnification of at least 250 diameters is usually needed for resolving it into its lamellae, though the pearlite of blister steel can often be resolved with a magnification of 25 diameters. The more rapidly pearlite is formed, the higher the magnification needed for resolving it.

GRAPHITE.

(Ger. Graphit, Fr. Graphite), definite metaral.

Definition. The free elemental carbon which occurs in iron and steel.

Composition. Probably pure carbon, identical with native graphite.

Genesis.—Derived in large part, and according to Goerens wholly, from the decomposition of solid cementite. Others hold that its formation as kish may be from solution in the molten metal, and that part of the formation of temper graphite may be from elemental carbon dissolved in austenite. It is the stable form of carbon in all parts of the diagram.

Occurrence.—(1) As kish, flakes which rise to the surface of molten cast iron and usually escape thence.

(2) As thin plates, usually curved, *e.g.*, in grey cast iron, representing carbon which has separated during great mobility, *i.e.*, near the melting range.

(3) As temper graphite (Ger. Temperkohle, Ledebur) pulverulent carbon which separates from cementite and austenite, especially in the annealing process for making malleablised castings.

Graphite and ferrite are sometimes associated in a way which suggests strongly that they represent a graphite-austenite eutectic. But the existence of such a true eutectic is doubted by most writers.

Properties.—Hexagonal. H. 1—2. Gr. 2·255. Streak black and shining, lustre metallic; microscopic colour, iron black to dark steel grey, but always black when seen in polished sections of iron or steel under the microscope; opaque; sectile; soils paper; flexible; feel, greasy.

TROOSTITE.

(Fr. Troostite, Ger. Troostit.) Probably aggregate. (Arnold, troostitic pearlite.)

Definition.—In the transformation of austenite, the stage following martensite and preceding sorbite (and osmondite if this stage is recognised).

Constitution and Composition. An uncoagulated conglomerate of the transition stages. The degree of completeness of the transformation represented by it is not definitely known and probably varies widely. Osmond and most others believe that the transformation, while generally far advanced, yet falls materially short of completion; but Benedicks and Arnold (9) believe that it is complete. The former belief that it is a definite phase, *e.g.*, a solid solution of carbon or an iron carbide in either β or γ iron, is abandoned. Its carbon-content, like that of austenite and martensite, varies widely.

Occurrence.—It arises either on reheating hardened (*e.g.*, martensitic steel) to slightly below 400°, or on cooling through the transformation range at an intermediate rate, *e.g.*, in small pieces of steel when quenched in oil, or quenched in water from the middle of the transformation range, or in the middle of larger pieces quenched in water from above the transformation range. With slightly farther reheating it changes into sorbite; with higher heating into sorbitic pearlite, then slowly into granular pearlite, and probably indirectly into lamellar pearlite. It occurs in irregular, fine granular, or almost amorphous areas, coloured darker by the common etching reagents than the martensite or sorbite accompanying it. A further common means of distinguishing it from sorbite is that it is habitually associated with martensite, whereas sorbite is habitually associated with pearlite.

Areas near the boundary between troostite and sorbite are sometimes called troosto-sorbite.

Properties.—Hardness, intermediate between that of the

martensitic and the pearlitic state corresponding to the carbon content of the specimen. In general, the hardness increases, the elastic limit rises, and the ductility decreases as the carbon-content increases. Its ductility is increased rapidly and its hardness and elastic limit lowered rapidly by further tempering, which affects it much more markedly than sorbite.

SORBITE.

(Fr. Sorbite, Ger. Sorbit.) Aggregate. (Arnold, sorbitic pearlite.)

Definition.—In the transformation of austenite, the stage following troostite and osmondite, if this stage is recognised, and preceding pearlite.

Constitution and Composition.—Most writers believe that it is essentially an uncoagulated conglomerate of irresoluble pearlite with ferrite in hypo and cementite in hyper-eutectoid steels respectively, but that it often contains some incompletely transformed matter.

Occurrence.—The transformation can be brought to the sorbitic stage (1) by reheating hardened steel to a little above 400°, but not to 700°, at which temperature it coagulates into granular pearlite; (2) by quenching small pieces of steel in oil or molten lead or even by air-cooling them; (3) by quenching in water from just above the bottom of the transformation range, Ar_1 Sorbite is ill-defined, almost amorphous, and is coloured lighter than troostite but darker than pearlite by the usual etching reagents. It differs further from troostite in being softer for given carbon content, and usually in being associated with pearlite instead of martensite, and from pearlite in being irresoluble into separate particles of ferrite and cementite.

As sorbite is essentially a mode of aggregation, it cannot properly be represented on the equilibrium diagram. Its components at all times tend to coagulate into pearlite, yet it remains in its uncoagulated state at all temperatures below 400°.

Properties.—Though slightly less ductile than pearlitic steel for given carbon content, its tenacity and elastic limit are so high that a higher combination of these three properties can be had in sorbitic than in pearlitic steels by selecting a carbon content slightly lower than would be used for a pearlitic steel. Hence the use of sorbitic steels, *e.g.*, first hardened and then annealed cautiously, for structural purposes needing the best quality.

MANGANESE SULPHIDE.

(Fr. Sulphure de Manganese, Ger. Schwefelmangan), MnS. (Arnold and Waterhouse). Metaral.

Occurrence, &c.—Sulphur combines with the manganese present in preference to the iron, forming pale dove or slate grey masses, rounded in castings, elongated in forgings.

FERROUS SULPHIDE.

(Fr. Sulphure de Fer, Ger. Schwefeleisen), FeS. Metaral.

Occurrence.—The sulphur not taken up by the manganese forms ferrous sulphide, FeS, which, probably associated in part with iron as an Fe—FeS eutectic forms by preference more or less continuous membranes surrounding the grains of pearlite. Colour, yellow or pale brown.

Sulphur Prints.—When silk impregnated with mercuric chloride and hydrochloric acid (Heyn's and Bauer's method) or bromide paper moistened with sulphuric acid (Baumann's method) is pressed on polished steel, the position of the sulphur-bearing areas, whether of FeS or MnS, records itself by the local blackening which the evolved H_2S causes. Phosphorus-bearing areas also blacken Baumann's bromide paper.

MISCELLANEOUS.

Eutectoid, Saturated, &c.—The iron carbon eutectoid is pearlite. Steel with more carbon than pearlite is called hyper-eutectoid, that with less is called hypo-eutectoid. Arnold's names "saturated," "unsaturated," and "supersaturated," for eutectoid, hypo-eutectoid, and hyper-eutectoid steel, respectively, have considerable industrial use in English-speaking countries, but are avoided by most scientific writers on the ground that they are misleading, because, *e.g.*, there is only one specific temperature, A1, at which eutectoid steel is actually saturated, and, if any other temperature is in mind, that steel is not saturated. Above A1 it is clearly under-saturated.

The objection to the names sorbite, troostite, martensite, and austenite, that each of them covers steel of a wide range of carbon content, is to be dismissed because a like objection applies with equal force to every generic name in existence.

RESEARCH WORK ON RAILS.*

BY M. H. WICKHORST.

SEVERAL years ago the number of rails in the United States that failed to give normal service or that broke under moving trains became alarmingly large. The worst condition was reached about 1905. The circumstances so agitated the executive officers of the railroads that the matter was made the subject of an investigation by the American Railway Association, an organisation of railroads dealing with matters of railroad operation of common interest. Reliable general statistics are not available to show numerically the exact condition as regards rail failures, but an idea may be obtained from the report of one road that, of a lot of 10,000 tons rolled and put in the track, 22 per cent. were removed in the first year on account of depressions in the head. When broken apart the majority of these rails showed interior openings in the head running lengthwise of the rail. Happily that extreme state of affairs has passed.

The wheel loads of the rolling equipment, locomotives, passenger cars, and freight cars had been rapidly increasing for 20 years or more. H. V. Wille has shown that the average total weight on drivers increased from about 69,000lbs. in 1885 to over 180,000lbs. in 1907, and reached a maximum of 316,000lbs. in that year. The average axle load increased from 22,000lbs. in 1885 to 48,000lbs. in 1907. Since then the axle loads have still further increased. During the same period the weight of rail (in main line track) increased from

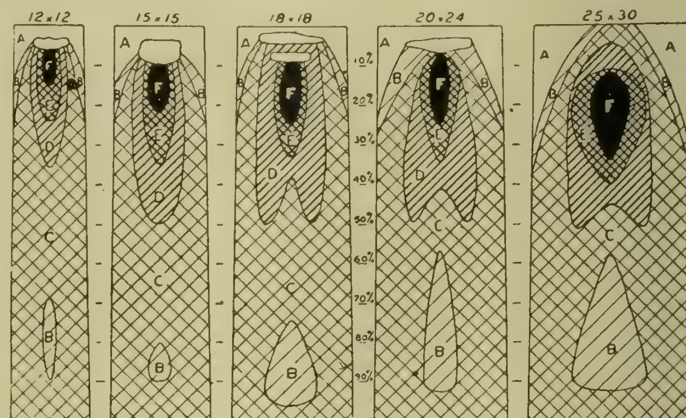


FIG. 1.—DISTRIBUTION OF PHOSPHORUS IN INGOTS OF DIFFERENT SIZES.

about 65lbs. to 75lbs. per yard to 85lbs. to 100lbs. per yard, which are also now the prevailing weights. The moments of inertia increased from about 15 to 20 to about 30 to 45. Considered as a girder, the strength of the rail increased about at the same rate as the axle load increased, the unit stress in tension remaining about the same or even decreasing slightly. The unit stress in compression, however, increased almost as the axle load increased, as the average width of rail head increased only from about 2⅜in. to about 2¾in., and the diameter of the wheels has remained about the same.

While the railroads were thus busy increasing the capacity of their motive power and cars, the steel mills were likewise endeavouring to obtain increased tonnage. These efforts took the form of eliminating unnecessary delays, installing larger converters, and more powerful machinery, using larger ingots, and sometimes of allowing less time for the chemical reactions. At the height of the tonnage endeavour in the rail mills, about five years ago, there was considerable rivalry between the different mills to produce the greatest tonnage, and it reached a condition that might almost be termed madness, that had only secondary regard for the quality of the product. The purchaser had the choice of buying rails as made by the mills or going without them. Recently, however, there has been a happy change, so that quality is being given due consideration

* Paper presented to the Sixth Congress of the International Association for Testing Materials, New York, September, 1912.

and mutual consultations are taking place. The change was due, presumably, to the chastening effect of slack orders for rails and the present state of public opinion.

In 1906 the American Railway Association took the matter in hand through its Committee on Standard Rail and Wheel Sections, which committee made a report in 1908 submitting some new designs for rail sections and also offering some tentative specifications. The matter was then referred to the American Railway Engineering and Maintenance of Way Association, now called (since April, 1911), the American Railway Engineering Association. The prevailing type of failure seems to have been the split head, generally termed "piped rail." The rails developed internal cavities, mostly in the head, running lengthwise of the rail for distances of several feet or more. It seems to have been the prevalent opinion that this and other types of failure as well as poor wear were due partly to internal structural defects and partly to finishing the head of the rail at too high a temperature. It was argued that the flanges were too thin, cooling quickly in the rolling, and that a temperature necessary to finish the flanges properly left the temperature of the head unduly high.

The remedy suggested was to make the flanges thicker, thus allowing of more uniform finishing temperature throughout the section. W. R. Webster wrote in 1901 as follows: "The cause of the trouble is now well known, it being due to the large mass of metal in the head carrying the heat so much longer than the thin metal in the flanges, thus preventing the

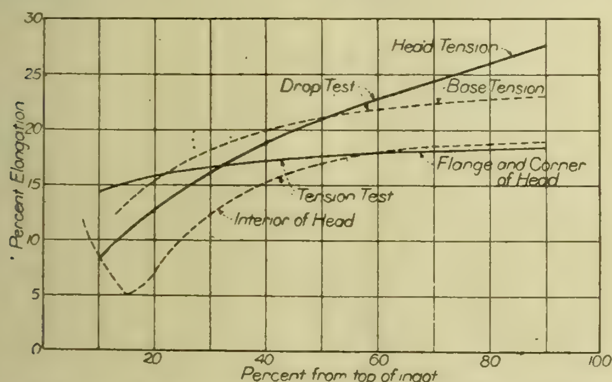


FIG. 2.—DUCTILITY OF RAILS IN DROP TEST AND TENSION TEST COMPARED.

work of rolling on the head at sufficiently low temperature to break up the coarse grain and produce the tough, good wearing rails desired." The committee of the American Railway Association later shared this same view to a large extent, as evidenced by the fact that the main feature of the rail designs they presented was the greater thickness of the flanges.

Recent work, which will be referred to later on, indicates that from the standpoint of safety high temperature of rolling is not detrimental, and that few if any failures can be attributed to this cause. I am referring now to splithead failures in Bessemer rails, as this was the prevailing type of failure, and open-hearth steel had not yet come into extensive use. The recent work has also shown that such failures occur almost entirely in badly segregated metal from the top part of the ingot, attended perhaps with laminations and slag seams. Under pressure the top of the head of the rail spreads sideways, and as the interior of the head with such metal as referred to cannot likewise extend laterally it develops a crack, which grows until failure results. Of course, increase of pressure would hasten the development of such failures.

It has indeed been more or less definitely recognised that split heads occurred mostly in rail from the upper part of the ingot, but the blame was placed on internal structural defects. The trouble is now well known, it being traceable to the large mass due to blowholes and pipes in that part of the ingot; the rôle of segregation was but vaguely recognised. In Europe the part played by segregation had probably been more definitely worked out years before, but the results of that work seem to have been overlooked or at anyrate their importance had not been fully appreciated in America.

As stated, the matter was turned over in 1908 to the American Railway Engineering Association to continue the work of investigation. This association appointed a committee, which continued the investigations started by the committee of the American Railway Association, and which also made a co-operative arrangement with the manufacturers of steel rails by which the latter furnish the material and facilities of their mills for research work, and the railroads furnish the engineer to conduct the tests under the direction of their committee and publish the results. The writer was honoured by selection for the position of engineer of tests and entered upon his duties February 1st, 1910. The full reports of the work done in 1910, together with other matter collected by the committee, are published in the Proceedings of the American Railway Engineering Association, 1911, Part 2, and it is expected that the reports of the work done in 1911 will appear in the Proceedings for 1912. Herewith are indicated some of the main results obtained, but those specially interested are referred to the above Proceedings for the full reports.

An investigation was made of ingots of Bessemer steel of various sizes from 12in. by 12in. to 25in. by 30in. at the bottom, all about 5ft. high, weighing from 2,000lbs. to 10,000lbs. As part of the investigation, a chemical survey was made of these ingots to determine the distribution of the various elements, particularly as influenced by the size of the ingot. The distribution of phosphorus in the various ingots is shown in Fig. 1. It may be said that carbon and sulphur show a similar distribution, differing, of course, as to the amounts in the various regions. The diagrams indicate that the regions of concentration of the phosphorus, figured as a percentage of the volume of the ingot, increase as the size of the ingot increases; the analyses also indicated that the maximum concentration of phosphorus in the segregated region increases as the size of the ingot increases.

The regions of negative segregation, that is, decrease of phosphorus below the average of the steel as poured, are also of considerable interest. The top of the ingot shows considerable decrease of the phosphorus, carbon, and sulphur, and this decrease extends downward along the sides a greater distance in the larger ingots. The analyses also showed that the amount of the deficiency in phosphorus increased in a general way as the size of the ingot increased. This means that the outer parts of the section of a rail made from the upper end are softer than the average of the steel from that ingot, and this has been found true of rails examined by means of tensile tests. There is also a region of milder negative segregation in the interior and lower part of the ingot.

A comparison of the ductility of rails made by the ordinary Bessemer process, as measured in the drop test and in the tension test, is interesting. Fig. 2 is given to show the comparison. The distance from the top of the ingot in per cent. of weight is plotted horizontally and the per cent. elongation is plotted vertically. The elongation in the tension test was measured on a test piece ½in. diam. with a gauge length of 2in. The elongation in the drop test was measured by placing gauge marks near the middle of the length of the piece of rail on the side in tension, 1in. apart, for a distance of 6in., and the length of the space which stretched most when broken under the drop was taken as the measure of the ductility of the rail in the drop test. Two curves are given showing the ductility of the rail bar in the drop test, one with the head in tension and the other with the base in tension. Two other curves are given showing the ductility of the rail bar in the tension test, one representing the interior of the head near its junction with the web and one representing the average of the flange and the upper corner of the head, as the results from these two locations were about the same.

In the tension test the exterior metal (as represented by the flange and the corner of the head) shows good ductility along the whole rail bar, although there is a general increase as we go down the ingot, from about 14½ per cent. elongation at 10 per cent. from the top to about 18½ per cent. elongation at 90 per cent. down. The results from the interior of the head near the web, however, differ considerably from these. There is fair ductility near the top, the elongation then drops off to less than 5 per cent. at about 15 per cent. from the top, and it then rises again and in the lower part of the rail bar averages slightly above the results from the exterior of the section.

In the drop test with base in tension, the elongation runs from 12 per cent. to 24 per cent. With the head in tension there is also a continuous increase in going down the ingot, but the differences in elongation are much greater (8 per cent. to 27 per cent.). In this respect there is considerable similarity between the ductility measured in the tension test

of samples from the interior of the head and the ductility as measured in the drop test with the head in tension. It would seem, therefore, that this latter test may be more useful to ascertain the ductility of the interior metal than the drop test with the base in tension, as is usual in inspection work. Since the above was first written the "Railway Age Gazette" (December 8th, 1911, p. 1,176), has abstracted an article by C. Frémont in "Le Génie Civil," in which Frémont comes to about the same conclusion, but goes a little farther and recommends that some of the top of the head be first planed off and the rail then tested by the drop test with the head in tension.

An investigation was made to determine the influence of the temperature at which the steel is rolled on the properties of Bessemer rails. A series of five ingots from one heat of Bessemer steel was rolled into rails, all in similar manner except as to the temperature at which they were rolled. One ingot was rolled "cold" and the temperature was increased with the succeeding ingots, finally rolling the last ingot very hot. The influence of the temperature as ascertained by these tests may be summed up as follows: The ductility and deflection in the drop test were influenced little, if any, by the rolling temperature. The number of blows that it took to break the rails in the drop test was uninfluenced by the temperature of rolling. The yield point and tensile strength in the tension tests were influenced little, if any. The elongation in the tension test decreased some as the temperatures increased. The influence of temperature showed most prominently in the tension test, in the reduction of area, which decreased as the temperature of rolling increased. The size of the grain, as shown by the microscope, increased as the temperature increased.

The general plan of our research work has been to direct attention to some one item which enters as a factor in the properties of the finished rail and attempt to obtain definite information concerning its influence by the experimental method of obtaining as great a range as practicable in the one item under consideration, but leaving all other conditions as near alike as possible. It is thus hoped to aid in establishing in the course of time the metallurgical principles and laws that apply to the manufacture of steel rails for the purpose of designing specifications and rail sections that will give uniformly safe rails of good wearing qualities, and at a minimum cost. The condition of co-operation in this work existing between the railroads and steel manufacturers is very gratifying and may confidently be expected to work to the best interests of the public, the railroads, and the steel mills.

Reinforced Concrete Barges.—Barges of reinforced concrete are being used on the Panama Canal because they cost less than steel and only a little more than timber. The ordinary flat-bottomed type is used, and the overall dimensions are 64ft. by 24ft. by 5ft. 6 7/16in. maximum depth. There are two longitudinal bulkheads, and lateral frames, 10ft. apart, strengthen the construction.

Sparks and Colliery Explosions.—In a paper recently read before the Institution of Mining Engineers at Birmingham, Mr. John T. Stirling and Prof. John Cadman described three explosions which had happened at the Bellevue Mine, Alberta, Canada, and expressed the view that they were caused by the ignition of inflammable gas by sparks emitted from falling stones. In two of the explosions no one was underground at the time, but in the third 30 lives were lost. Experiments were made with the hard siliceous rock composing the roof with the object of discovering its power of producing sparks. It was found that when a specimen was struck a glancing blow with a hammer, the surface of percussion glowed red hot for the instant, and that when two small pieces of the stone were struck one against the other sparks were seen, which varied in intensity with the energy applied. To obtain a play of sparks a steel flint-mill was used, and the sparks produced were of sufficient intensity to ignite coal-gas or methane very readily. The authors are satisfied that they have proved that sparks sufficient to bring about the ignition of inflammable gas can be produced by falls of roof in the No. 1 Bellevue seam, and as subsequent examination after each explosion showed that there had been falls of large masses of roof in areas where gas was in all probability present, the explanation of the explosions seems to them clear.

INCREASE OF BORE OF HIGH-SPEED WHEELS BY CENTRIFUGAL STRESSES.*

WITH FORMULÆ FOR FORCE AND SHRINK FITS.

BY SANDFORD A. MOSS.

RECENT advances in high-speed steam turbines and the apparatus driven by them have opened up a great many new problems. One of these is the fact that, under certain circumstances, unless proper precautions are taken, a high-speed turbine wheel, or the like, expands at the hub a sufficient amount to cause an appreciable increase in the bore, so as to make the wheel slightly loose upon the shaft and capable of pounding back and forth. This pounding causes a mechanical increase of the looseness, so that the machine soon gives evidence of distress. So far as the writer knows, the first one to direct attention to this problem, to suggest means of investigating it, and to offer a solution was Richard H. Rice, chief engineer of the Lynn works' turbine department, General Electric Company. The present paper gives an account of work on the problem done under the general direction of Mr. Rice by various members of his department.

Nature of Stresses in a Wheel or Ring.—It is the purpose first to give a general account of methods of computing stresses in

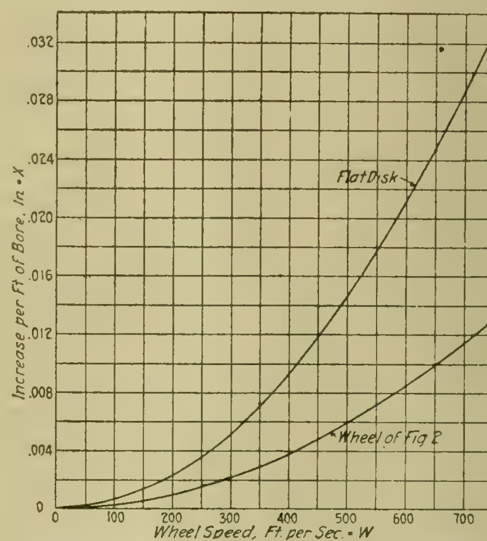


FIG. 1.—INCREASE OF BORE OF A ROTATING WHEEL.

Ratio of diameter of bore to diameter of disc = 0·353. This ratio may be changed considerably without appreciably affecting the results.

Approximate dead weight per lb. of disc (equal in both cases) = 100,000lbs. per foot of disc circumference at 534ft. per second.

circular bodies. When there is rotation this becomes a very intricate subject, and details and formulæ must be sought in works specially devoted to it. It is assumed that the disc is thin, that is, that the thickness is negligible compared with its diameter. Then conditions are the same at all points on a line parallel to the axis. This is not strictly true, as the central part of a hub is strained differently than the ends. However, in most cases this effect is slight. At each radius in the disc there are two stresses, one in the radial direction denoted by S_r and one in the tangential direction denoted by S_t. If we consider the effect of these stresses on the metal of a thin ring at the interior of the disc, we find the circumference of the ring to be increased mainly by virtue of the tangential stress, and the thickness mainly by the radial stress. However, when a metal is extended in one direction by a stress there is a shrinkage in a direction at right angles, the ratio of the deformations being called "Poisson's ratio," which we will denote by V. For ordinary kinds of steel this has a value of 0·3. That is, the increase of circumference of a thin ring in the interior of the disc is less than that which would be produced by the tangential stress if acting alone, by an amount which is 0·3 of the extension which would be produced by the radial stress acting alone. Similarly the increase in the thickness of the ring is less than

* Paper presented at the Boston meeting, May 17th, 1912, of the American Society of Mechanical Engineers.

that produced by the radial stress acting alone. In any case, the ratio of stress to extension per unit length produced by it if acting alone is given by the modulus of elasticity E, usually taken as 29,000,000lbs. per square inch; or, if l is the total extension in a distance L, we have the well-known law

$$E = \frac{S}{\frac{l}{L}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The combination of the above principles with the laws of the centrifugal forces on the various elements of the disc gives

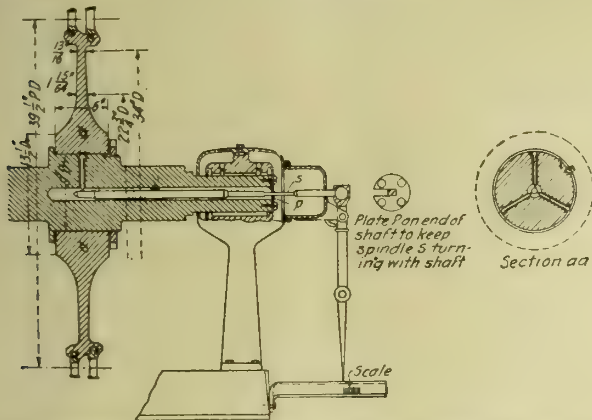


FIG. 2.—DIAGRAM OF DEVICE FOR MEASURING THE INCREASE OF BORE DURING ROTATION.

formulæ which enable computations to be made of the stresses in the disc at all points during rotation.

In order to determine the safety of a structure where there are stresses in more than one direction, it is necessary to find an effective stress which corresponds so far as yielding is concerned to the stresses in a specimen of the same material subject to simple tension is a testing machine. It is now almost universally agreed that Guest's maximum shear law is the proper one. This states that in cases such as the present, where there are stresses in two directions only with zero stress in the third, and where the stresses are either both tension or both compression, the greater of the two stresses is the effective stress. This effective stress is equal to a simple stress which would produce like results so far as yielding, safety, elastic limit, &c., are concerned.

This is not true, however, when there are stresses in all three directions, as in the case with a rotating disc of appreciable thickness, where there is change of stress in the axial direction; or with two stresses with opposite sign, as in the stresses in the hub due to force fits, discussed later. In such cases the maximum algebraic difference between the greatest and least of the stresses existing at a point taken with proper sign gives the effective stress or equivalent simple tension. In most cases of properly designed rotating wheels with a hole at the centre the maximum stress is the tangential stress at the bore. This is, therefore, the stress which is to be considered in order to ascertain if the wheel is safe, and is further the stress which must be determined in order to discuss the problem of the present paper.

Formula for Increase of Bore.—As we proceed outward from the bore in a rotating wheel, the radial stress mounts up rapidly, due to the fact that the centrifugal forces of the outer portions of the disc pull outward on the inner portions. The nearer the centre the less the material in the inner circle, and therefore the less resistance to radial elongation. At the bore there is no force whatever resisting radial elongation, so that the radial stress becomes zero as this inner diameter is reached. We have then on the inner wall of the cylinder forming the bore, material which is stressed only in the tangential direction, and the increase of circumference is exactly the same as if we had a straight bar of the same length stressed an amount equal to the tangential stress at the bore. This is expressed by the simple relation which is the fundamental equation of our problem:—

$$X = \frac{S_{to} D_o}{E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where

X = increase in diameter in inches of the bore, due to the centrifugal stresses at a given speed.
S_{to} = tangential stresses at the bore in pounds per square inch at the same speed
D_o = original diameter of bore in inches.
E = modulus of elasticity, 29,000,000lbs. for steel.

It can be shown that the stresses at any point in a given wheel or at a similarly situated point in any other wheel of similar proportions, are directly proportional to the square of the peripheral wheel speed. Hence the increase of bore in which we are interested varies directly with the square of the peripheral wheel speed with a given wheel. In any case of the same or geometrically similar wheels, the increase per foot of bore increases directly with the square of the wheel speed.

Numerical Magnitude of Increase of Bore.—The allowable values of the tangential stress at the hub are quite high, since a centrifugal load is one of the easiest loads which can be applied, and is of the nature of a pure dead load in a beam. It is not possible to apply or remove a centrifugal load suddenly, but only in the most gentle manner. Also the maximum stress usually occurs only in a single set of fibres which are reinforced by adjacent fibres with decreasing stresses. There need be no "factor of ignorance," and maximum stresses can be known with as great accuracy as it is desired to give to the mathematical computations. In many cases 20,000lbs. per square inch is a conservative stress. In some cases with special grades of steel 30,000lbs. per square inch is possible. For a wheel with 12in. bore and 30,000lbs. maximum stress the increase in bore computed from (2) is 0·0124in., which is an appreciable amount. For other stresses and other dimensions of bore the increase of bore is in direct proportion. When the stress is 29,000lbs. per square inch the increase in bore is 1 mil per inch of bore.

Fig. 1 gives numerical values of increase in bore for various wheel speeds for two different shapes of disc. The upper curve is for a disc of uniform thickness. This shape is only possible with comparatively low wheel speeds, and the stresses become excessive with speeds ordinarily used in

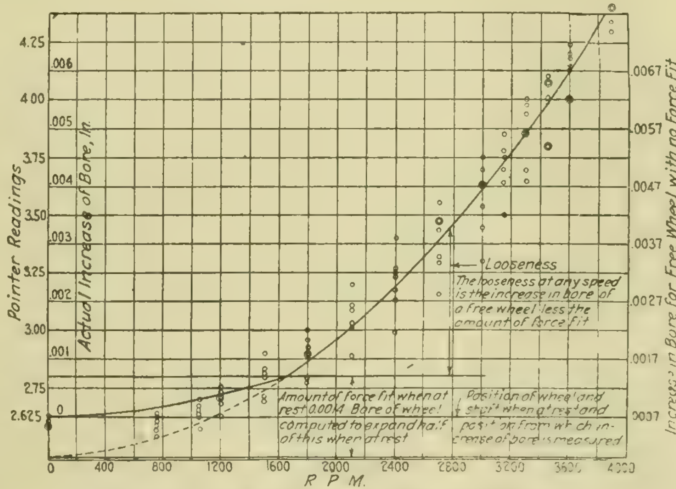


FIG. 3.—INCREASE IN BORE OF A ROTATING WHEEL.
Points from test with rotating wheel (Table I.): curve drawn from computations

turbine practice. The lower curve is for a disc of the more efficient shape shown in Fig. 2. In both cases the computations are made for a turbine bucket wheel with a load due to centrifugal force of buckets at 3,600 revs. per minute of 100,000lbs. per foot of circumference. The shapes of the curves are affected somewhat by the magnitude of this outer dead load. In both cases the ratio of bore to disc diameter is 0·353. The curves are not greatly affected by difference in this ratio. The curves give very nearly the values of increase in bore per foot of bore for various wheel speeds for a disc of uniform thickness, which is about as poor a shape as would ever be used, and for a disc of what is probably as efficient a shape as would ever be used, with an average bucket load.

The increase in bore for any shaped disc whatever will probably lie between the two curves.

The curves of Fig. 1 were constructed as follows: The wheel whose dimensions are given in Fig. 2 is the wheel of a standard steam turbine with a web diameter of 34in. In the course of the design of this wheel the maximum stress was computed for the rated speed, 3,600 revs. per minute, and came out about 20,400lbs. per square inch. From the value of this stress and formula (2) the increase in bore

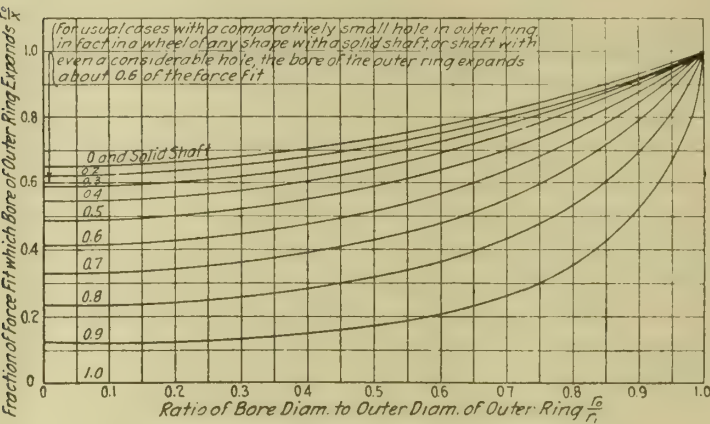


FIG. 4.—RATIO OF EXPANSION OF BORE TO FORCE FIT.
Figures on curves denote ratio of diameter of hole in inner ring to diameter of bore of outer ring $\frac{r_2}{r_0}$

at the rated speed was found. The effective bore, taking account of keyways, was 12in. From the law that the stress and hence the increase in bore varies directly with the square of the wheel speed, the lower curve of Fig. 1 was drawn, taking bore as 12in., however.

Next was taken the case of the upper curve for a flat disc. From the formulæ for stresses in flat discs given in Stodola's "Die Dampfturbinen," fourth edition, pp. 248 and 249, can be deduced the following formula for the tangential stress at the bore of a flat disc S_{to}, where S_{r1}, is the radial stress at the circumference due to bucket load, W is the wheel speed in feet per second, and R is the ratio of bore diameter to web diameter.

$$S_{to} = 0{\cdot}0261W^2\ (0{\cdot}7R^2 + 3{\cdot}3) + \frac{2S_{r1}}{1 - R^2} \quad . \quad . \quad (3)$$

This is for a steel disc whose modulus of elasticity is 29,000,000lbs. per square inch, Poisson's ratio 0·3 and density 0·28lb. per cubic inch. The centrifugal force due to the bucket load on the previous disc, 100,000lbs. per foot of circumference, was taken as being applied to a flat disc of about the same weight, giving 1¼in. axial width, and 34in. web diameter. This gives a radial stress S_{r1} of 6,670lbs. per square inch at the circumference of the flat disc. The ratio of the diameter of bore to the web diameter R was taken as in the previous disc 0·353.

Experimental Measurement of Increase of Bore of a Rotating Wheel.—The magnitudes of the increase of bore in a number of actual turbine wheels, as determined by substituting computed stresses in equation (2) came out so large that it was decided to make an actual measurement of the increase in bore when a wheel was rotating. Fig. 2 shows the apparatus diagrammatically and Fig. 3 the results obtained. The turbine wheel was mounted on a shaft with a light force fit. A delicate micrometer arrangement was provided, so that change in bore of the wheel while it was rotating with the shaft could be observed. The wheel was gradually increased in speed, and meanwhile the readings of the micrometer taken. These showed that the bore expanded at each speed an amount almost exactly the value computed by the methods previously given. The micrometer arrangement proved very positive, and there was no uncertainty regarding the measurement of the increase of bore. The maximum amount measured was about 0·007in. The observations were accurate to about 0·0005in. The wheel was forced on the shaft with a force fit of 0·0014, so that it was loose on the shaft by about 0·0056 at maximum speed. The duration of the tests was not great enough to show any difficulty due to this.

Measuring Device.—The measuring device shown in Fig. 2 consisted of three pistons sliding in radial holes in the shaft pushed outward by means of a tapered plug moving axially in a hole in the centre of the shaft. The motion of the central plug was given by means of a lever with a ball and socket joint, fulcrumed so as to give considerable multiplication, and read by a pointer passing over a scale. A displacement of the pointer by 1in. corresponded to an increase of bore of 0·004in. The position of the pointer was certain to within about ⅛in. motion along its scale, corresponding to 0·0005in. change of bore. While the speed was being varied an attendant kept his hand on the pointer, moving it back and forth a slight amount so as always to keep it just in the proper position. As the speed varied from low values to maximum value the pointer moved a distance of about 2in., so that the change in bore was quite perceptible. Owing to the fact that the increase of bore varies with the square of the speed there was no perceptible change below about 750 revs. per minute, and this was the lowest speed used. The highest speed was 3,900 revs. per minute.

TABLE I.—*Readings of Pointer in Tests with Rotating Wheel, conducted March 11th*, 1911.

R.P.M.	Test No. 9		Test No. 10		Test No. 11		Test No. 12		Test No. 13	
	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down
0	2·61	2·62	2·62	2·63	2·62	2·63	2·63	2·62	2·61	2·62
750	2·61	2·54	2·63	2·59	2·63	2·59	2·64	2·62	—	—
1050	2·64	2·58	2·70	2·68	2·68	2·67	2·66	2·70	—	—
1200	2·69	2·63	2·74	2·72	2·72	2·74	2·72	2·75	—	—
1500	2·72	2·70	2·80	2·82	2·82	2·80	2·84	2·90	—	
1800	2·78	2·79	2·90	2·96	2·92	2·90	2·96	3·00	—	—
2100	2·84	2·89	3·03	3·10	3·02	3·10	3·11	3·20	—	
2400	2·99	3·14	3·18	3·25	3·18	3·24	3·26	3·40	—	—
2700	3·16	3·30	3·32	3·44	3·32	3·48	3·48	3·56	—	
3000	3·30	3·45	3·54	3·63	3·54	3·63	3·70	3·75	—	—
3150	3·50	3·64	3·70	3·78	3·75	3·85	3·85	3·85	—	
3300	3·65	3·70	3·85	3·94	3·85	3·98	4·00	4·00	—	—
3450	3·80	3·80	4·01	4·08	4·00	4·08	4·10	4·08	—	—
3600	4·00	4·00	4·13	4·20	4·15	4·18	4·24	4·20	—	—
3750	4·12	4·12	4·24	4·28	4·30	4·29	4·34	4·33	—	—
3900	4·30	4·30	4·34	4·34	4·38	4·38	4·38	4·38	4·38	4·38

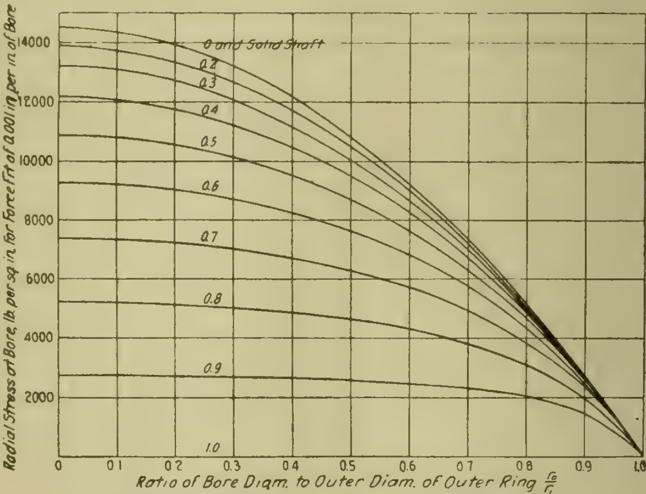


FIG. 5.—RADIAL STRESS AT BORE S_{r0}. FORCE FIT OF 0·001IN. PER INCH OF BORE.
Stress is directly proportional to force fit per inch of bore. Figures on curves denote ratio of diameter of hole in inner ring to diameter of bore of outer ring $\frac{r_2}{r_0}$

Calibrating Sleeve Test.—In order to find the relation between the readings of the pointer and the actual values of increase of bore, and also to demonstrate that the apparatus would give correct measurements at high speed, a calibrating sleeve was made. This was a thin sleeve bored out at each end so as to be a sliding fit on the shaft and with two different bore diameters in the central portion, either of which could be brought over the pistons of the measuring device. Readings of the pointer were taken at each of these bores, stationary and rotating, at various speeds. The stationary readings gave the motion of the pointer for the known change of bore calibrating the entire apparatus. The readings while rotating showed that the instrument gave correct readings at all speeds.

Test with Rotating Wheel.—Next the rotating wheel was pressed on the shaft. A number of readings of the diameter

of shaft and bore of wheel showed that the average amount of force fit was 0·0017in. After this, a pair of outside calipers was set to fit the shaft at various points, and a pair of inside ones set to fit the wheel bore. The difference between the two calipers was then found by means of a thickness gauge. The mean of these observations gives 0·0011in. as the amount of force fit. The mean of these two values 0·0014in. is considered to be the actual amount of force fit. It was necessary to know the amount of this force fit in order to make comparisons between the computed and observed amounts of increase of bore of the rotating wheel, since the wheel at zero speed is expanded somewhat.

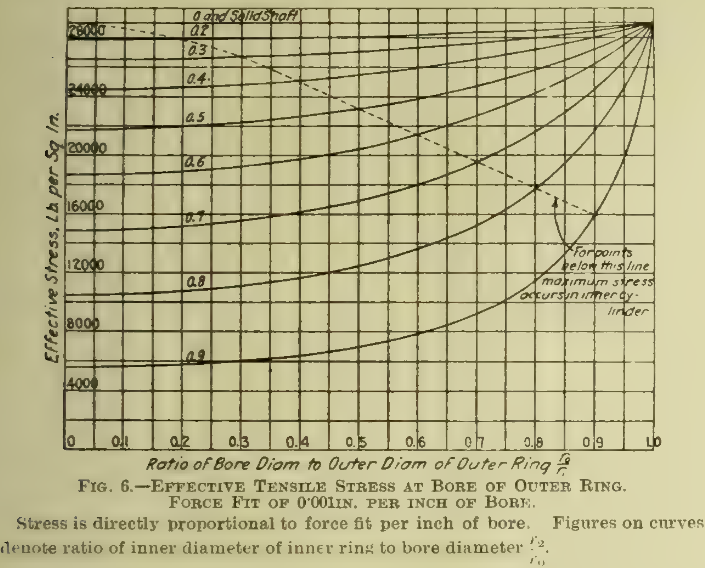


FIG. 6.—EFFECTIVE TENSILE STRESS AT BORE OF OUTER RING. FORCE FIT OF 0·001IN. PER INCH OF BORE.
Stress is directly proportional to force fit per inch of bore. Figures on curves denote ratio of inner diameter of inner ring to bore diameter $\frac{r_2}{r_o}$.

Fig. 2 is a diagram of the arrangement of the apparatus when the wheel was on the shaft. Readings of the pointer were taken at various speeds, as shown by Table I., and the results plotted in Fig. 3. The pointer readings, as well as the corresponding values of actual increase in bore as shown by the previous calibrations, are given on the left. Owing to the fact that the wheel was forced on the shaft, the measured diameter of the wheel at zero speed is greater than the actual free diameter of the wheel. By methods given later, it was computed that the wheel was expanded by the force fit one-half of the difference in free diameters, the remainder being compression of the shaft. Hence the base line for increase in bore of the wheel from the free condition is the lower line of Fig. 3, which is 0·0007in. below the base line for increase in bore from the actual initial value when on the shaft. The computed curve for the increase in bore for the free wheel at the various speeds is drawn in Fig. 3, beginning with the lower base line. At that speed where the expansion of the free wheel is equal to the amount of the force fit, 0·0014in., the shaft is just released from its compression and wheel and shaft are just of the same diameter. For speeds beyond this point the wheel expands exactly as if there was no initial force fit. The wheel is loose on the shaft by whatever increase in bore occurs beyond this point. The observed points are seen to fit very closely the computed curve. For all speeds below that at which the wheel and shaft just touch there is compression of the shaft and expansion of the wheel by the force fit, the amount being successively less as the speed increases. The effective force fit at any speed is the difference between the force fit at rest, and the expansion of the free wheel at the given speed. The effective force fit is, therefore, the difference between the dotted curve and the upper horizontal line. As shown later, when there are different amounts of force fit with a given wheel and shaft, the expansion of the wheel is always a constant fraction of the amount of force fit. This is one-half in the present case. Hence the curve showing the increase in bore of the wheel, as the force fit is gradually relieved, is drawn half-way between the dotted curve and the upper horizontal line.

In the present case the amount of the force fit is comparatively small. It was originally intended to repeat the experiments with successively increasing amounts of force fit. The measuring apparatus was arranged so that it could be torn down and reassembled without change in the absolute initial value of the readings. This was done with the idea of actually measuring the change in the initial bore of the wheel when put on the shaft with different amounts of force fit, giving curves in Fig. 3 which would start with successively greater amounts of force fit and meet the curve of a free wheel higher up. However, the results of the first experiment agreed so closely with the theory, and everything was so obvious after study of the subject that no further experiments were made.

Design of Wheels subject to Increase of Bore by Centrifugal Stresses. The method used to prevent difficulty due to loose wheels is to force the wheel on the shaft with a force fit, or difference in diameters between wheel bore and shaft, greater than the computed amount of increase of bore at maximum speed. In some cases this has resulted in large amounts of force fit requiring very heavy pressures for forcing. Special material is necessary for the bushings between the wheel and the shaft. However, all of these points have been successfully met, and ill-effects due to loosening of the wheels wholly eliminated.

In some cases the wheel hubs do not fit along their entire length but only in places. The radial pressure, when the fit only occurs for a short distance, is obviously increased by the ratio of the total length of hub to the actual length of the fit. The numerical values of this radial pressure on the bushings, computed by methods discussed below, come to very high figures in many cases. Of course, some relief is offered by the fact that this pressure is pure compression, and that the metal of the bushings is constrained on nearly all sides, so that the resistance to flow is considerable. Under such circumstances much higher values of compression stress can be used than when there is no resistance to the deformation which the compression tends to cause. There is reason to believe that in the ideal case of a piece subject to pure compression in every direction, there would be no failure even with an infinitely large stress. It is to be remarked that when the force fit is just sufficient to prevent loosening at full speed and the shaft is solid, the effective stress in the hub due to the force fit when at rest is exactly equal to the stress at full speed.

Computation of Force and Shrink Fits with Steel.—A complete treatment of the subject based on the maximum shear law previously mentioned is given for the first time so far as known. It turns out that a wheel hub is affected only for a very short distance outward, so that the nature of the

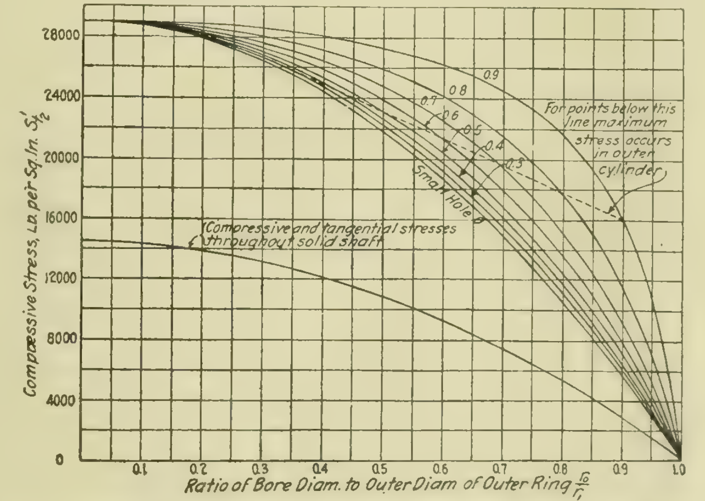


FIG. 7.—COMPRESSIVE TANGENTIAL STRESS S'_t, AT INNER DIAMETER OF INNER RING. FORCE FIT OF 0·01IN. PER INCH OF BORE.
Stress is directly proportional to force fit per inch of bore. Figures on curves denote ratio of inner diameter of inner ring to bore diameter $\frac{r_2}{r_o}$. Values given are the maximum effective stresses in inner ring.

outer portion has little or no influence. The condition near the hub in a flat disc with an outer diameter only 10 times the diameter of the bore is practically the same as in a disc with an infinitely large outer diameter. We therefore consider only the case of a ring forced upon another ring of equal axial length. We estimate the outer diameter of the outer ring so as to make it equivalent so far as expansion is concerned to a given wheel of any shape. For instance, for a solid wheel comparatively thin at the outer portion, we would estimate the equivalent flat disc to have one-half or one-third the diameter of the wheel. For a wheel with

spokes, we have little more than the hub only. We also estimate an equivalent inner ring if we do not have a solid or hollow shaft. Owing to the comparatively slight influence of the parts of the rings furthest from the fit, a considerable error in estimation of the diameters of the equivalents will cause comparatively small error in the results.

Figs. 4, 5, and 6 give amount of expansion and stresses in an outer ring or hub pressed or shrunk on inner ring or shaft. The difference in the free diameters is called the force fit, which we will denote by X. When the hub is in place on the shaft, and there is no rotation so as to loosen, it is expanded by a certain amount F'_0. The shaft is also compressed by a considerable amount. The sum of the increase of hub bore, F'_0, and the compression of the shaft is evidently the amount of the force fit. Fig. 4 gives values of $\frac{F'_0}{X}$ the fraction of the force fit which the hub expands. Fig. 5 gives the radial stress at the bore of the hub, which is also the stress at the outside of the shaft, as well as the pressure per square inch between when there is actual contact for the full length of hub. Fig. 6 gives the maximum effective stress at the bore of the hub. This is the greatest stress in the system unless the shaft is hollow and relatively thin. Figs. 5 and 6 are for a force fit of one mil per inch of bore. Stresses for other values are in proportion.

The abscissæ of these figures give the ratio of the bore to the outer diameter of the hub. The upper curve in each of these three figures is for a solid shaft or one with a small hole, and the other curves are for rings with various sizes of holes. When the abscissa is zero the outer diameter of the hub is infinitely large as compared with the bore. The curves are nearly horizontal for a considerable distance in this region, and the results for an outer diameter 10 times the diameter of the bore, that is, a ratio of 0·1, are almost the same as for an infinite outer diameter. The values for an outer diameter five or three times the diameter of the bore change but little. Similarly, as will be seen by noting the curves for the various values of the ratio of the diameter of the hole in the shaft to the shaft diameter, the hole has but little influence unless it is comparatively large. The usual case of a shaft with a comparatively small hole is practically equivalent to a solid shaft. As will be seen by a study of the curves, the case where the diameter of the hub is seven times the diameter of the bore, giving a ratio of 0·14, and where the hole in the shaft is 0·3 of the shaft diameter, gives very nearly the results of any usual case. Hence, for usual cases the hub bore expands about 0·6 of the amount of the force fit, and for a force fit of 1 mil per inch of bore the radial stress is about 13,000lbs. per square inch, and the effective tangential stress is about 27,000lbs. per square inch.

For a solid shaft, however, the maximum effective stress is 29,000lbs. per square inch for a force fit of 1 mil per inch of bore, regardless of the character of the wheel or hub. The stress for other amounts of force fit is in proportion. Force fits of 1 mil per inch are therefore about as large as will give no permanent set of the hub for steel and a solid shaft. Force fits up to about $1\frac{1}{2}$ mils are frequently used. These give some set of the fibres very near the bore. This set is almost entirely eliminated by the elastic force of the outer fibres if the hub is ever removed from the shaft, however. Fig. 7 gives the maximum stress (at the inside) in the shaft or inner ring. This is usually less, but for a relatively thin ring may be greater than the stress in the hub. A solid shaft has a stress one-half as great as one with a small hole.

A rational expression for the force in pounds to press the hub on the shaft is

$$0{\cdot}12\ d_0 l S_{r0}$$

where l is the length, d_0 the diameter of bore of the hub in inches and S_{r0} the radial stress at the bore found from Fig. 5. The coefficient of 0·12 was obtained from actual tests, and gives a coefficient of friction of 0·038. For a force fit of 1 mil per inch of bore the forcing pressure in our usual case is about 1,560lbs. per inch of bore and per inch of hub length. The forcing pressure, of course, varies widely on account of the influence of surfaces and lubricant. The formula gives an average value.

ELECTRIC INDUCTION FURNACE FOR CAST STEEL.*

BY. C. H. VOM BAUR.

THE electric induction furnace for making steel has been in regular commercial operation in Europe for over 10 years and more than 30 of these furnaces have been installed. It can be built in sizes of 8 or 16 tons capacity and 30-ton furnaces have been projected. These electric furnaces are of the Roechling-Rodenhauser induction and resistance type, operating on single, two, or 3-phase alternating current, utilising any convenient voltage of commercial circuits; 25-cycle is preferred, but 60-cycle current can be used in the smaller sizes.

The furnace action is similar to any ordinary transformer. The primary coil receiving the incoming current is subdivided into series of steps, usually five, which, by the aid of a switch, regulate the current and consequently the heat in the metal bath. Seventy per cent. of the secondary current is induced directly in the bath, which is really one short-circuited turn of the secondary winding of the transformer. The remaining energy, 30 per cent., is induced in a large copper-bar secondary winding, wound directly over the primary winding, which receives the electric current from the alternator. This auxiliary secondary current is carried to two steel pole plates, set beneath the lining, one at each end of the bath. The magnesite lining covering these plates is the hearth of the furnace and becomes the conductor of electricity when red hot, acting similarly to the filament of a Nernst lamp. There are, therefore, two sets of currents in the bath, the main or induced current and the auxiliary induced or resistance current. The advantage of having this combination of electric currents is manifold—it increases the thermal and electric efficiency of the furnace, increases the heat of the steel in the main hearth, thus facilitating the refining, and precludes any interruption of the current flowing through the metal. There are, therefore, no involuntary fluctuations of the current, which is consumed at an absolutely steady rate.

The heat of the metal can be kept at any practicable temperature between a dull red and 2,600° C., which is the limiting temperature of the magnesite lining. As there is no involuntary change in the current and no violent fluctuations take place, there is no strain placed on the prime mover. In other words, in this type of furnace there is nothing to wear out but the lining, the furnace runs quietly and there are no carbon particles blowing through the air, owing to the method of melting the steel. The current being steady and the amount of steel in the furnace being known, the heat, with a little practice, can be accurately determined by observing the ammeter reading. The heat regulation of a Roechling-Rodenhauser furnace is absolutely under control. No foreign ingredients can inadvertently get into the metal bath, such as sulphur, phosphorus, carbon, nor any other substances from any flame, electrodes, or lining.

The heat is produced only by heavy induced current going directly through the bath, which allows superheating of the metal without the introduction of oxygen or nitrogen. The metal contains a minimum of gases. This reduces the amount of ferro-silicon and ferro-titanium required, if either of these alloys are used. Contrary to the gas-heated or other furnaces or converters, the chemical composition and temperature can be regulated independently of each other. The composition of the metal can easily be changed and the temperature held at the desired point. The metal can be poured at the temperature to suit the conditions; for large castings into crane ladles, for small castings into bull ladles or small hand ladles. The furnace being of the tilting variety facilitates pouring, and the removal of the slag through the slag opening at the rear.

The items entering into the manufacture of steel castings are essentially as follows:—

Raw Material.

(1) The raw material.
(2) The oxidation loss.

* Abstract of paper presented at the Pittsburg meeting of the American Foundrymen's Association.

Conversion Cost.

(3) Electric current consumption and its cost per kilowatt-hour.
(4) Fluxes and additions.
(5) Labour.
(6) Tools, repairs, and lining.
(7) Depreciation and interest.
(8) Auxiliary apparatus.

When charging cold material for making steel castings, the cheapest steel scrap can be used to advantage and refined to the desired degree.

When charging hot metal for refining or merely for thorough deoxidation and segregation, it may be taken directly from the blastfurnace, from a mixer, a cupola, or some other furnace.

At Dommeldingen, Germany, pig iron was charged into an induction furnace of the Roechling-Rodenhauser type and refined as follows:—

	Analysis of charge, per cent.	Analysis of cast, per cent.
Carbon	4·0	0·5
Phosphorus	1·8	0·025
Sulphur	0·2	0·03
Manganese	—	0·76
Silicon	1·0	0·056

Duration of conversion, 5 hours.

Such impure hot metal is rarely charged in the electric furnace, except under unusual conditions, as it can be partly refined by a gas-fired furnace cheaper than in an electric furnace.

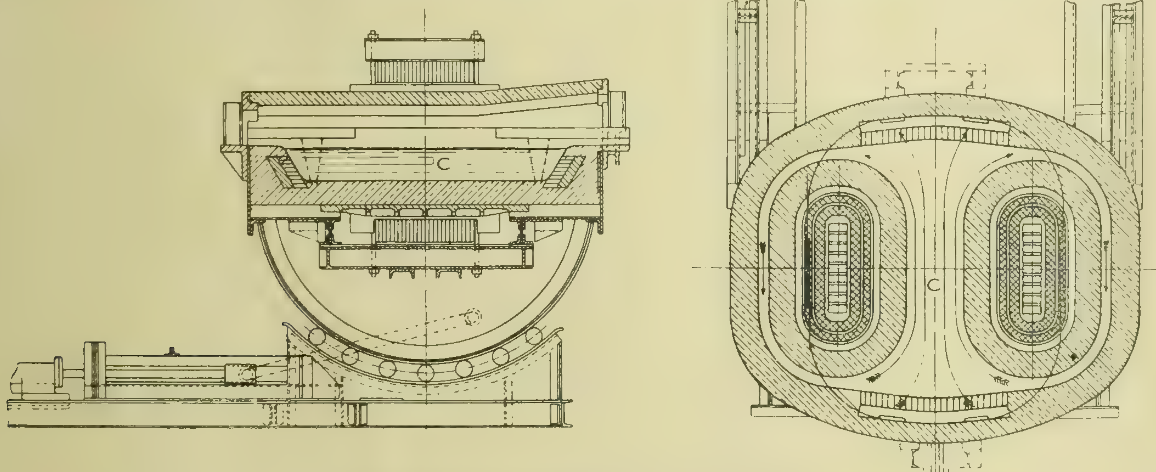
It takes longer to treat cold metal than hot and only three-fourths of the bath is tapped when cold metal is used instead of the entire contents of the furnace when hot metal is treated. When charging cold metal, 25 per cent. of the hot charge remains in the furnace to complete the electrical circuit. Cold scrap consisting of many pieces does not meet the required conditions, as the voltage in the bath is as low as 2 or 3 volts, which is not sufficient to overcome the contact resistance between the numerous pieces of scrap.

When operating the furnace, the limestone and roll scale are charged and the bath is refined until the analysis shows that no phosphorus remains, or the process may be stopped before this, thus retaining some phosphorus and cheapening the process. This refining usually lasts an hour or so, varying somewhat with the initial percentage of phosphorus present. During this dephosphorising period the carbon is greatly reduced and the silicon is almost or entirely eliminated. This first slag is then thoroughly removed by tilting the furnace backwards at a slight angle and rabbling off the slag. Then, according whether mild or hard steel is required, a quantity of carbon is added to meet the requirements. At this time sufficient ferro-manganese is charged to meet the specifications. The desulphurising slag is then added. As soon as this is melted, the bath and slag are deoxidised, the slag becomes white, and owing to its increased temperature absorbs the departing sulphur rapidly, the refining being dependent upon the temperature at the point of contact between the metal and the slag. The gases are expelled and likewise the small particles of slag which are expelled by deoxidation; in the same manner the sulphides are absorbed by the white lime slag, while a small part of the sulphides volatilises; otherwise, the composition of the bath remains the same.

TABLE I.—*Chemical Analyses and Physical Tests of Annealed Electric Steel Castings.*

Carbon, per cent.	Silicon, per cent.	Manganese, per cent.	Sulphur, per cent.	Phosphorus, per cent.	Tensile strength pounds, per sq. in.	Elongation, per cent.
0·12	0·13	0·53	0·014	0·011	51,920	22·5
0·10	0·20	0·48	0·015	0·020	58,000	23·5
0·23	0·30	0·59	0·021	0·025	66,840	24·0
0·26	0·31	0·62	0·018	0·022	68,550	20·0
0·32	0·35	0·83	0·012	0·025	79,650	20·5
0·35	0·32	0·68	0·022	0·023	85,340	15·5
0·37	0·35	0·71	0·009	0·017	95,300	15·0

A carbon analysis is then obtained and the necessary modifications are made. In the case of alloy steels, the alloys are only added after the deoxidation period, so that any loss which might be caused through the formation of slags is avoided. This deoxidation period usually lasts an hour. It is this deoxidation period, so thorough and effective, which has no parallel in any gas-fired furnace or converter. The sulphur has meanwhile almost entirely disappeared, being reduced as low as 0·01 to 0·005 per cent. After a last analysis shows that the deoxidation of the metal is complete, the furnace is tapped without further additions. Castings weighing from ½lb. to the capacity of one or more furnaces are regularly made. The chemical analyses and physical tests of annealed electric steel castings are given in Table I.



SECTIONAL VIEWS OF ELECTRIC INDUCTION FURNACE.

Launch of H.M.S. "Audacious." — There was recently launched from the yard of Messrs. Cammell, Laird, & Co., Birkenhead, H.M.S. "Audacious," which is the first armoured vessel of the "Dreadnought" type to be built on the Mersey. She is of the same type as the "King George V.," and the group will consist of four vessels, viz.: "King George V.," "Centurion," "Ajax," and "Audacious." The type is an improvement on that of the four battle-ships of the "Orion" class, although similar in general design. Whereas the "Orion" and her sisters have a displacement of 22,500 tons, the class to which the "Audacious" belongs displace slightly over 23,000 tons, and have a length of 555ft., as compared with 545ft., with a beam of 89ft. as compared with 88½ft. As with all the "Dreadnoughts," Parsons turbines are the type of propelling machinery used, and those for the "Audacious" are being manufactured by Cammell, Laird, & Co. The boilers of the ship will be of the Yarrow type. In the main battery are 10 13·5in. guns, mounted in five twin turrets on the centre line of the ship, while the guns for repelling torpedo attack are 20 of 4in. calibre, or four more than in the "Orion" class. The total cost of the "Audacious," exclusive of the cost of the guns, is estimated at £1,774,513.

A LARGE GERMAN BLASTFURNACE GAS ENGINE PLANT.

In a recent issue of "The Iron Age," Mr. C. A. Tupper furnishes a description of the gas-engine driven power plant of the Gewerkschaft Deutscher Kaiser, at Bruckhausen, on the Rhine, which is the largest plant of its kind in Europe, having a present capacity of 60,000 h.p. It supplies current for operating coal mines, coke ovens, and a by-products plant, blastfurnaces, open-hearth, converter, and electric steel plants, roughing and finishing mills and fabricating plants, foundries, machine shops, &c., and also for transmission over an independent electric system serving the communities and industries of an extensive district. The power-house has a length of 459ft., and a width approximating 252ft., being divided longitudinally into three parts, viz.: Electric plant 110ft., blowing engine-house 116ft., and a central bay, open at the bottom along each of the two 459ft. sides, which contains auxiliary machinery, offices, and various conveniences. This takes up the remaining 26ft. of width.

The electric plant contains 12 units. All of the engines are 4-cycle double-acting machines, 9 tandem and 3 twin-tandem, built by Thyssen & Co., Mülheim-Ruhr, Germany.

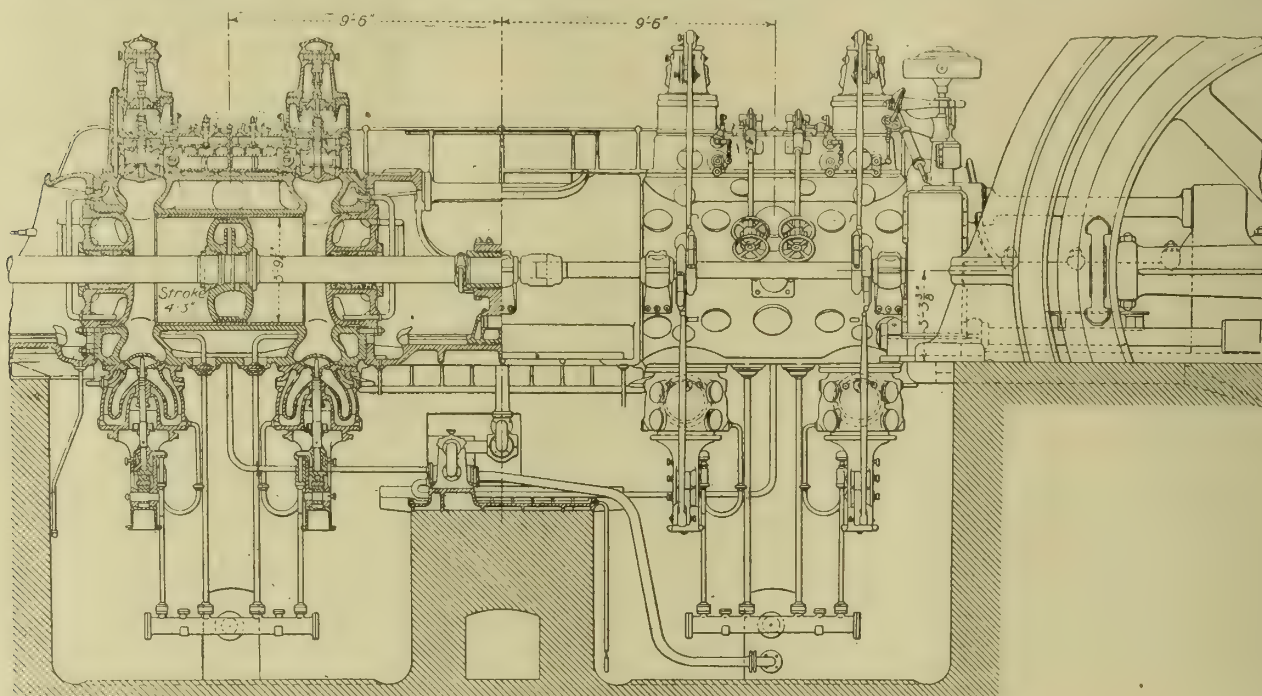


FIG. 1.—SECTION THROUGH CYLINDERS OF THE THYSSEN GAS ENGINE.

Of the first-named, four have cylinders 43·3in. diam. by 51·3in. stroke, and to each engine a 1,450 kw. generator is direct connected; five have cylinders 48in. diam. by 55in. stroke, and drive 2,000 kw. generators direct coupled, and the three largest have 51in. cylinders by 59in. stroke. To each of these a 4,500 kw. generator is direct connected.

All of the gas used in the engines is that generated by the blastfurnaces, from the tops of which it is taken in the usual manner. After passing through 22ft. dry dust catchers, the gas is collected in two gas mains, 8ft. 6in. diam., with a third held in reserve, which discharge to the 13ft. header of the cleaning plant proper. Here the first receptacles are three dry dust catchers, 19ft. 8in. diam. by 25ft. high, elevated sufficiently above the yard level to enable the accumulated dust to be dumped into dust-proof enclosed railroad cars of a special design, in which the dust is transported to a briquetting plant. Each dust catcher can be shut off by means of a valve of the water-sealed, mushroom type, and is connected to two wet scrubbers arranged in series. The six wet scrubbers are arranged in rows of three, those of each row operating in parallel while the two rows work in series. These scrubbers, the towers of which are 24ft. diam. by 32ft. high, are of the Zschocke type designed and built by the Zschocke Werke, Kaiserslautern, Germany.

After leaving the scrubbers the dry cleaned gas is collected in one large main of 13ft. diam., which distributes it to six hydraulic fans of the Schiele type. The branch pipes to each fan are 4ft. 3in. diam. The outlet pipes discharge the clean gas into water separators and thence into another collecting main 12ft. 6in. diam., whence it returns to the blastfurnace stoves in two 8ft. pipes, which form a complete loop around the furnace plant. Water-sealed mushroom valves, conveniently arranged, permit the shutting off of any section of this ring main for cleaning purposes.

From this collecting main the gas available for the power plant is drawn off in a 6ft. 6in. pipe and carried to the secondary cleaning plant. The latter consists of five Schiele fans discharging the fine gas into water separators and thence into the final collecting main, which is connected to a gas holder 60ft. diam. and of about 175,000 cub. ft. capacity. Another branch of 5ft. diam. by-passes the gas holder, giving direct connection to the power plant when the holder is not in service.

The raw gas contains, on an average, 3·5 grains of dust per cubic foot. It leaves the Zschocke scrubbers with a content of about 0·50 grain per cubic foot, which drops to about 0·11 grain per cubic foot after the preliminary Schiele cleaning fans. In the secondary cleaning plant the amount of the dust is reduced to about 0·013 grain per cubic foot, the gas arriving at the engines with a content of about 0·011 grain per cubic foot (about 0·025 gramme per cubic metre). The dust determinator is of the Stroehlein cotton-method type.

The temperature of the gas entering the cleaning plant (carried in unlined pipes across the ore yard for about 1,200ft.) is 194° to 212° Fah. This temperature is reduced to about 79° Fah. behind the Zschocke washers and is about 70·5° after the Schiele fans. The temperature of the water supply is 79° and the waste leaves the washers at 104°. The quantity of water consumed for cleaning is 30 galls. per 1,000 cub. ft. for the preliminary processes, in which quantity the Zschocke scrubbers share with 23 and the Zschocke fans with 7 galls. The quantity of water used in the secondary plant, having the Schiele fans, is 12 galls. per 1,000 cub. ft., so that a total of about 42 galls. per cubic foot is required.

This quantity of water, which will, of course, vary somewhat either way according to conditions, is remarkably small; but, due to the scarcity of the supply, the management has adopted every possible means of conserving it. All of the waste water from the gas cleaning plant is carefully collected and carried in launders to two settling tanks for purification. One of these, which has nine compartments with a total area of 80,000 sq. ft., takes the water from the wet scrubbers only, while the waste from the preliminary and secondary fans is purified in the smaller tank of four compartments and 27,000 sq. ft. area. The waste water passes through the compartments of the tanks in series and thence flows to a reservoir to be pumped over a cooling tower 150ft. by 45ft. in area, with

natural draught. For this purpose there are three centrifugal pumps, and the cooled water is raised by another set to the top of a distributing tower. The residue from the cleaning tanks is removed by means of grab buckets operated from gantry cranes and conveyed to the coal mines on the property for use in backfilling.

The gas enters the power plant through a ring main 6ft. 6in. diam., from which feeder pipes of 20in. diam. branch off to the engines. This piping is laid underneath the floor and is readily accessible. The combustion air for the engine cylinders is taken in through ducts which are integral with the concrete foundations and terminate on the outside in pockets protected by wire gauze. The piping for the cooling water, compressed air used in starting, &c., is laid similarly to that for gas. All of the conduits and the pipes, which are painted different colours to indicate their purpose, have been arranged on the loop system, to enable the engines to be supplied from either direction, and any unit may be cut off from the mains common to all without interrupting the service of the others.

Immediately adjacent to each engine there is a gas receiver, with supply pipes leading to each cylinder. The gas supply reaches the engine from the receiver through the left-hand pipe in Fig. 2, and a handhole is provided in the port leading to the gas valves, through which any deposit can be removed as required. The gas supply to each end of each cylinder can be independently adjusted by means of the hand wheels shown on the side of the right-hand cylinder in Fig. 1, which actuates a link motion for opening or closing the valves shown immediately above the cylinder in Fig. 2.

The air supply pipe is the larger pipe at the left in Fig. 2, and a valve is provided by means of which the proportion of air drawn in can be regulated by hand. Having these two adjustments, the engine can be run on gas of any quality suitable for power purposes, since, by varying the relative degrees of opening and closing of these valves on the air and gas supplies, the proportion of air to gas can be varied through as wide a range as needed. Closer regulation, to meet all operating conditions, is obtained through the additional throttle valves shown above the left-hand cylinder in Fig. 1, which are under the direct control of the governor.

Particular attention is directed to the arrangement for admitting gas and air to the engine cylinder. As will be observed from Fig. 1, the gas valve is on the same spindle as the main inlet valve, and there is also a sleeve on this spindle which, when the valve is seated, covers the air port. Thus the opening to air is always proportional to the opening for gas. These inlet valves are operated by an eccentric on the side shaft and have a constant opening, the governing being effected not by varying the lift or duration of opening of this valve, but by means of the throttle valves.

The exhaust valves, it will be seen, are located below the cylinder and are wholly contained in separately cast boxes, which can be readily removed when the valves require examination or any work is to be done on them. The engine exhaust, as shown in Fig. 2, is through suitable piping to concrete muffler tunnels on either side of the plant, connected to the atmosphere through steel stacks.

The jacket is cast integral with the cylinder, but it is fitted with a renewable liner which takes all the wear. Both cylinder heads and pistons are water cooled, as shown in Fig. 1, and the water cooling of the exhaust valves and their casings has been amply provided for. The cooling water enters at about 72° to 78° Fah. and leaves at 104° to 108° Fah., flowing into a reservoir. From this it is pumped to a cooling tower equipped with fans, where the temperature is reduced to about 75°. Approximately 12 galls. of water, on the average, is needed per brake horse-power hour.

For the cylinders there is forced lubrication, oil being pumped in through a pipe piercing the water jacket, extending diagonally to the top of the cylinder in Fig. 2. As the engines are 4-cycle machines, the side shaft has to be geared down. This is effected by spiral gearing located between the flywheel and one of the main bearings, and the gearing runs in an oil bath, being fully enclosed. The crank shaft has three bearings, that on the right hand having a spherical seat. The brasses are lined with white metal, and the lubrication here is also forced. There is no central oil supply, but each engine has been provided with its own system throughout. As the oil is used it flows to a tank in the basement under each engine and is pumped back through a strainer. This keeps it clean enough so that filtering has to be done only once in two or three months.

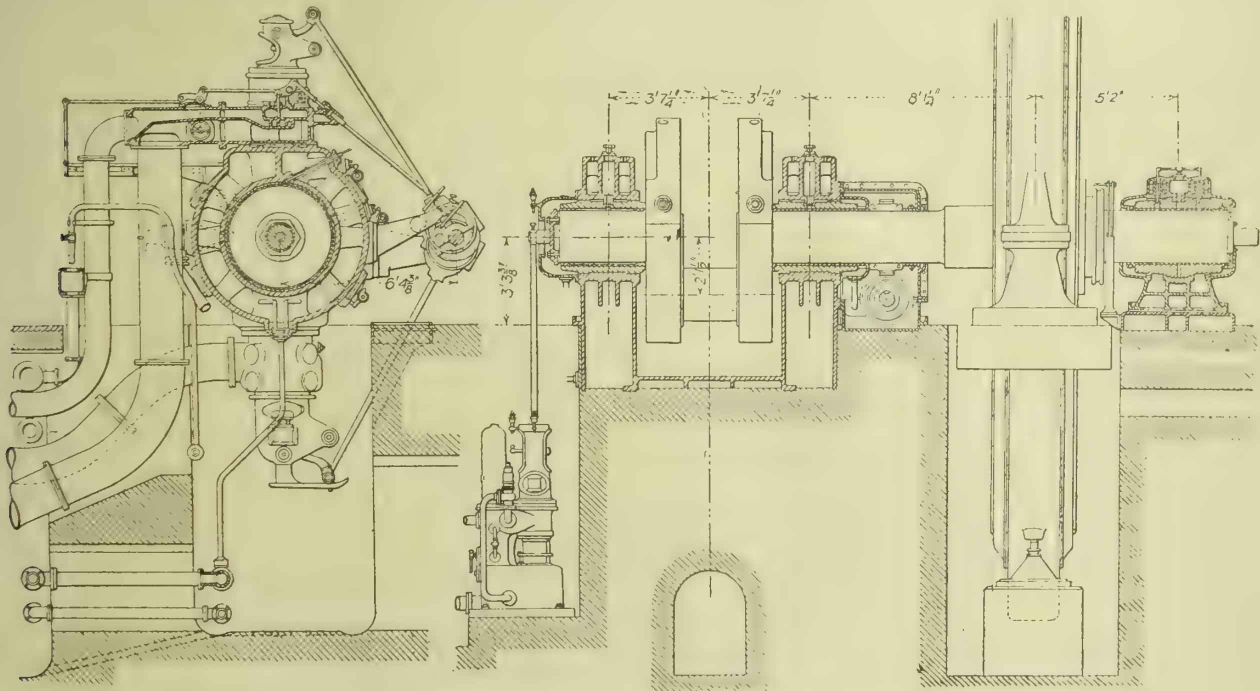


FIG. 2.—SECTIONS THROUGH CYLINDER AND BEARINGS OF THE THYSSEN GAS ENGINE.

The two cylinders in tandem are connected at the top by steel stays supplementing the tie piece. Similar stays lead from the first cylinder to the top of the main bearings, and this tends to relieve the engine frame from the bending strains which were so frequent a source of trouble in earlier days. The two piston rods are connected by a crosshead and the tail rod at the rear is suitably guided. Hence the pistons and the rods float in the cylinders, and their weight is taken off the glands. The gland packings are metallic.

The generators direct coupled to the gas engines are alternating-current machines of the usual revolving field type, supplying 3-phase, 50-cycle current at a terminal pressure of 5,000 volts. Each is built with a heavy flywheel rotor, except for the three first installed, which have separate flywheels. The earlier machines were from the Siemens-Schuckert Werke, while the latest have been constructed by the Allgemeine Elektricitäts Gesellschaft, Berlin. When the production is greater than the local needs the excess current can be turned into the great independent system of the Rheinische-Westphalische Elektricitäts Werke, which has a network of

transmission lines connecting districts in a great part of the coal, iron, and steel producing section of North Germany. The sale of current for this purpose is a good source of income for the Gewerkschaft Deutscher Kaiser, although its own consumption has averaged of late about 70 per cent. of the maximum capacity of the plant.

The longitudinal central compartment, or bay, 26ft. wide, has its main floor depressed below the level of the generator and blower rooms. On this are installed the pumps, air compressors and tanks, exciter units, transformers, &c., as well as an oil filter plant; while on a floor above are offices, a dining-room, lockers, toilet-rooms, &c., and a storage battery installation for supplying the incandescent lights, thus preventing the station from being plunged into darkness should the main lighting system fail. The battery for ignition current is also located here.

The blowing engine plant of the Gewerkschaft Deutscher Kaiser extends the full length of the 489ft. power-house and occupies 116ft. of the width, being separated from the electric plant only by the central bay. The arrangement of this is, in general, similar to that of the generator-room, already described, the layout of the gas, combustion-air and starting-air piping, cooling system, lubrication, &c., being the same. There are seven blowing engines for supplying blast furnaces, one being always held in reserve. Four of these units have gas cylinders and blowing tubs 43·3in. and 100·8in. diam., respectively, with 51·2in. stroke, and are capable of delivering about 40,000 cub. ft. of free air per minute at the maximum rated speed of 90 revs. per minute; while three units have cylinders and tubs 48in. and 114·3in. diam. by 55·1in. stroke, with a displacement of 56,000 cub. ft. of free air per minute at the same speed. The usual working speed limit is, however, 80 revs. per minute, with corresponding capacity. The normal operating pressure of the units is 10·3lbs. above atmosphere; but each is so designed as to enable it to deliver air at higher pressures up to 14·7lbs. or beyond, with corresponding reduction in volume. All were built by Thyssen & Co.

Each of the furnace blowers discharges into an air dome, manufactured by the engine builders, which is 40ft. long and 10ft. diam., made of ⅝in. steel with welded seams. This effectually prevents any leakage of air or oil and serves as a pressure equaliser, eliminating vibrations in the cold blast piping and elsewhere. The blast pipe leading to each of the six furnaces is 4ft. diam., with accordion expansion joints, and the system is arranged so that any engine may supply the blast for any furnace. In practice two engines are usually blowing one furnace.

There is also in the blower department two Thyssen twin-tandem blowers for converter service, which have cylinders and tubs 48in. and 74·8in. diam. by 55·1in. stroke. Each also operates at 90 revs. per minute and has a maximum capacity of about 50,000 cub. ft. at 36lbs. pressure and can also blow to 44lbs. These blowing engines are stated to be the largest of the type thus far built. The machines have no governors, but each is operated from the stand between the cylinders, where the main gas throttle valve, the hand wheels for mixing adjustment and ignition timing, as well as the hydraulic unloading levers, are conveniently located, so that one man can handle the engine.

During so-called blowing up periods of the converters a valve in the blast main is open, while another valve in a branch pipe to the atmosphere is closed. During the blowing down periods the engine continues at full speed and the air is blown into the atmosphere by reversing the hydraulic valves. It is, of course, peculiar to the operation of converters that greater demands must be made upon the quick regulation of the air pressure and volumetric delivery of a blower for this service than upon one discharging to blastfurnaces. When the first of the two machines just described was under consideration it was argued that steam-driven blowers would be more reliable, or that, if gas-driven blowers were chosen, the 2-cycle engine would be better adapted to the service than the 4-cycle, particularly at low speeds. It has proved, however, that the 4-cycle machines installed at Bruckhausen, as well as similar converter blowing engines from Thyssen & Co. have fulfilled all of the demands made upon them. In addition to the unloading device at the blower end, by means of which the air volume from full load to no load can be instantly varied, with speed constant, the valve gear of the engine is so designed that the speed can be varied at will within wide limits. How closely this latter regulation works is demonstrated by the fact that the machine operates with absolute reliability at speeds as low as 20 revs. per minute, while the maximum speed, 90 revs. per minute, can be attained within 20 seconds.

Greater demands cannot be placed upon even a first-class steam blowing engine, and it is self-evident that these characteristics have put the 4-cycle gas blowing engine in a position to compete successfully also with steam turbine-driven or motor-driven turbo blowers or 2-cycle gas blowers. According to figures given to the writer by Thyssen & Co. some time ago, they have already built over 200,000 h.p. in machines of this type. They also make a point of the fact that, in addition to equal service reliability, the 4-cycle gas blowing engines have about three-fold the efficiency of steam-driven blowers and lead the 2-cycle gas blowing engines in mechanical and thermal efficiency together by 8 to 15 per cent. There is also the further benefit, in comparison with steam turbine-driven blowers, that a condensing system with high vacuum is essential to the successful operation of a turbine plant, and this requires a large quantity of cold water, or about eight times as much for a gas engine of the same capacity, which in many places can only be obtained at high cost.

The works of the Gewerkschaft Deutscher Kaiser include extensive coal mines, some of the shafts of which open upon the plant area; a large coke and by-products plant; six blast-furnaces recently remodelled, with inclined electric skips, hoists, bell tops, &c.; a 9-furnace Siemens-Martin open-hearth steel plant; a basis Thomas converter plant of 5 to 16-ton units; new electric refining furnaces; two blooming mills, seven finishing mills, &c., as well as allied fabricating, founding and machine plants under the control of the owners, viz.: the Thyssen interests, which, next to the Krupps, are the largest of the German metal industries.

In the preparation of this article the writer is indebted for the description of the cleaning plant and considerable other data to H. J. Freyn, who made a much more thorough inspection of the Bruckhausen power system than the writer did, and whose work in connection with the largest gas engine installations in the United States is well known.

OIL SPRAYERS FOR INTERNAL-COMBUSTION ENGINES.

We illustrate herewith a design of oil sprayer for internal-combustion engines, the invention of Mr. K. Crossley and Mr. W. Webb, of Crossley Bros., Ltd., Openshaw, Manchester, and Mr. L. Barley, by means of which the thorough atomisation of heavy oils is effected without the aid of compressed air. The sprayer consists of a plain cylindrical body A, fitted with a separate nozzle C. Inside and concentric with the body is a sleeve D having at its lower end a coned face which seats on a corresponding coned face on the nozzle. On the surface of the sleeve and parallel with the axis are ducts, through which the oil from an annular passage formed in the sleeve is conveyed to a second annular passage surrounding a number of spiral or tangential grooves cut across the coned face of the sleeve, and through which the oil is driven. In the centre of the sleeve is a needle valve B, the lower end of which seats on the coned face in the centre of the nozzle. In operation this valve is lifted outwards by the pressure of the oil acting on either a difference in area between the upper and lower portions of the spindle of the needle valve, or on the available area formed by the grooves cut in the seating of the needle valve. A spring H is used to keep the needle valve on its seat when oil is not being forced through the sprayer. When the pressure of oil lifts the valve the oil passes through the spiral grooves causing the usual whirling action which enables the oil to be delivered through the central hole under the seating in a cloud of spray. The lift of the valve is adjusted by means of a set screw K. A cap partially enclosing the spring secures the sleeve D firmly in the nozzle, the sleeve being of good length to prevent undue leakage past the valve spindle and having a small overflow pipe L to take any oil which does leak back to the oil supply.

In operation, the oil fuel is forced through the inlet of the oil sprayer into the annular chamber G from whence it passes through the ducts F to the lower annular J and is forced through the ducts cut on the face of sleeve at E. The pressure of the fluid acting on either a difference in area between the upper and lower portions of the spindle of the needle valve, or

on the available area formed by grooves cut in the seating of the needle valve, as described below, overcomes the resistance of the spring H, and raises the needle valve from its seat, allowing the oil after passing through the ducts on the face of the sleeve at E to be delivered through the central hole in the nozzle in the form of a very fine spray. By means of the adjusting screw K the lift of the valve B may be adjusted whilst the sprayer is working. If adjustment were not possible in this manner, and if owing to wear the lift of the needle valve increases, undue loss of oil will take place past the valve spindle before it is closed by the spring, and this loss of oil will unfavourably affect both the atomisation of the liquid fuel and the time of ignition.

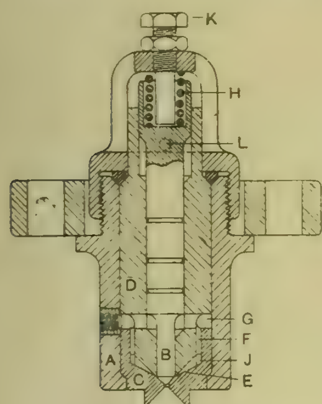
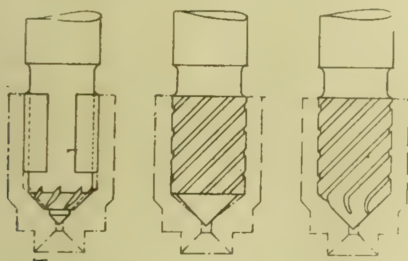


FIG. 1.—OIL SPRAYER FOR INTERNAL-COMBUSTION ENGINES.

Fig. 2 illustrates a needle valve on the face of which and across the coned seat of which are ducts similar to those described as being cut in the sleeve D. Instead of the ducts being cut across the entire face seating is left in the centre to effectually close the hole in the centre of the nozzle C. In operation this valve is lifted by the pressure of the oil acting on the available area of the ducts mentioned above, the lift of the valve being adjusted to give the desired effect. Figs. 3 and 4 show further modifications of the needle valve, the illustrations of which, together with the above description, are self-explanatory. The sprayer may be used in any position,


FIG. 2. FIG. 3. FIG. 4.

horizontal, vertical, or inclined. In place of a plain cylindrical body one with a jacket through which may be circulated water or oil or air for cooling purposes, or a body arranged with fins or ribs on the exterior surface, cooling being effected either by a natural or by a forced circulation of air, may be employed.

Crane Accidents.—While a number of shipyard hands were testing a 100-ton crane at the Alexandra Wharf, Belfast, on the 18th inst., a portion of the structure collapsed without the slightest warning, carrying three men with it into the deep-water dock. Two men were either killed by the falling machinery or drowned, while a third was rescued in an exhausted condition.—A crane accident occurred on the 20th inst. at the building operations in connection with the extension of Elderslie School, Glasgow. Heavy roof girders were being hoisted by the large crane. During the progress of the work the chain slipped, and the jib of the crane fell, knocking down the foreman, who was more or less injured.

The Location of Icebergs.—An important experiment is being carried out on the steamer "Royal Edward," which recently left for Montreal. Dr. M. Coplans, of Leeds University, is determining, by the aid of an apparatus of his own invention, the saline contents of the water of the Atlantic Ocean at various points of the route. It is anticipated that the experiments, which are being carried out with the co-operation of the United States and Canadian Governments, will have an important bearing upon the locating of icebergs with a view to rendering disasters like that of the "Titanic" impossible. On his arrival in America Dr. Coplans is to proceed to the ice zone in the United States cruiser "Chester."

CORRESPONDENCE.

The Textile Institute.

To the Editor of "The Mechanical Engineer."

Sir,—I should be obliged if you will allow me to reply through your columns to the many applications I have had from your readers for particulars of membership of the Textile Institute. Membership of the Institute is open to anyone engaged in the textile and allied trades, which, of course, include all who are interested in furnishing power, light, and all kinds of textile machinery. It was frequently stated by engineers who spoke at our Hawick Congress that the Institute had justified its existence, even if it had done nothing else but form a common platform on which steam, gas, oil, and electrical engineers could meet and discuss power problems from a common point of view. The series of papers which were given at Hawick are only the beginning of a complete investigation which this Institute proposes to make into the whole subject of "Mill Driving." I use the term "Mill Driving," not only to include prime movers, but also the various methods of distributing power. An early opportunity will be taken of having a series of papers on this latter feature, in which an opportunity will be given for those interested in the various forms of power distribution to state their cases. May I take this opportunity, sir, of thanking you for the excellent report you have given of our Congress proceedings, and of expressing the hope that our work may continue to merit such recognition? I shall be very pleased to send a circular giving details of what the Institute is, and what it is doing, to any of your readers.—Yours truly,

GEO. MOORES, Secretary.

The Textile Institute, 14, Cross Street, Manchester, September 23rd, 1912.

INDUSTRIAL AND TRADE NOTES.

Mineral Output of South Africa.—The mineral output of the Union for 1911 was valued at £47,679,294, as compared with £43,674,249 for 1910.

Additional Blastfurnace at Palmers.—An additional blastfurnace belonging to the Palmer Shipbuilding Company, Jarrow, was started on Monday last. There are now four furnaces working, and it is four years since so many were in blast

Patrol Steamer for Canada.—The Canadian Government has, we learn, placed an order with Messrs. J. I. Thornycroft & Co., Southampton, for an armed steamer for Customs patrol on the St. Lawrence river. The vessel will cost about £55,000, and will be built of steel, with twin screws and triple-expansion engines of 2,000 h.p.

Light Railway.—The Board of Trade have recently confirmed the undermentioned Order made by the Light Railway Commissioners: York Corporation Light Railways (Extensions) Order, 1912, authorising the construction of light railways in the City of York, in extension of the light railways authorised by the York Corporation Light Railways Order, 1908.

The World's Trade.—The half-yearly return of the trade of the principal countries of the world, issued by the Board of Trade, shows that Great Britain still holds the lead, both in imports and exports, although the United States of America are within a few thousand pounds of the British record in exports, and Germany is a good third. In imports Germany, with a figure more than £40,000,000 behind the United Kingdom's total, comes second.

New South Wales Government Railways.—Reporting upon the working of the Government railways and tramways in New South Wales during the year ended June 30th last, the Chief Commissioner states that the earnings of the railways amounted to £6,491,473, and the tramways to £1,581,393, the surplus after paying working expenses and allowing for interest on capital invested being respectively £415,513 and £57,696, as against £553,998 and £47,627 in the preceding year. The working expenses of the railways showed an increase of £478,530, due to the additional train mileage, the higher rates of pay granted to the staff, and the larger expenditure on permanent way renewals.

Tubeworkers' Lock-out Ended.—The dispute at Messrs. Stewarts and Lloyds' tubeworks, Dalmarnock, in which over 2,000 men were involved, has now practically come to an end. The firm report that for some days past they have been receiving numerous applications from the men for permission to resume work, and at a conference held on the 20th inst. between a deputation of the operatives and the management, a settlement

was arrived at, with the result that about 1,800 employés restarted on Tuesday last. The men have, we learn, accepted the conditions laid down by the firm, and it is stated that an understanding has been come to that in future there will be no sectional strikes, the frequency of which led to the present dispute.

Russian Pig-iron Production.—In view of the great inconvenience experienced in Russia owing to the shortage of native pig iron, it is becoming increasingly important to look about for further sites where pig iron can be produced at reasonable cost. As a result of investigations which have been made, it is thought that smelting works might profitably be erected on the banks of the Kama and its tributaries. The question of a sufficient supply of good fuel is, of course, of cardinal importance; and as far as can be ascertained at present, it is thought that a good supply of iron ore and of fuel can be obtained in the neighbourhood of the Kama, and that pig iron could therefore be produced at a low cost.

New Substance for Picture Films.—An invention of interest to manufacturers of films for cinematograph displays has been introduced by Boroid, Ltd., 104, High Holborn, London. At present cinematograph films are made of celluloid, which is highly combustible. The new substance, which is known as "Boroid," is intended to supersede celluloid in the manufacture of films, and it is claimed for it that it is neither inflammable nor explosive. A demonstration of the new material was recently given, when it was explained that no celluloid was used in its composition. A piece of raw film was placed in a lantern for a considerable period with the light focused on it. When it was removed no change seemed to have taken place. A piece of film was afterwards held in the flame of a match. It crumpled up, but no flame resulted.

Development in Marine Propulsion.—A steamship having four screws and driven by combined reciprocating and turbine machinery is nearing completion at the Neptune Shipyard, Walker-on-Tyne, of Messrs. Swan, Hunter, & Wigham Richardson, Ltd., This vessel, to be named "Reina Victoria-Eugenia," is intended for passenger and cargo service of the Cia. Transatlantica between Barcelona, Cadiz, and Central and South America. Messrs. Swan, Hunter, & Wigham Richardson were amongst the first to take up and advocate the combination of reciprocating and turbine engines in order to effect savings in consumption of fuel in vessels of considerable size and speed. It is understood that the investigations and experiments of the Wallsend firm have inclined them to favour an arrangement of four screws rather than three screws.

Mining Output of India.—The Chief Inspector of Mines in India, in his report for 1911, states that the average number of persons working in and about the mines was 146,336. There was an increase in the output of coal, which was 12,048,726 tons, compared with 11,387,716 tons raised in 1910. The coal trade generally was better than in 1910, and improved throughout the year. The output per person employed during the year was (*a*) below ground 174 tons, and (*b*) above and below ground 113 tons. The average in England for the 10 years ending in 1910 was 287 tons per person employed above and below ground. There was a large increase in the output of mica, which was 31,686 cwts., compared with 21,375 cwts. raised in 1910. The output of manganese ore was 111,426 tons, compared with 468,669 tons in 1910.

The Yorkshire Electric Power Company.—The directors' report on the progress of the company for the half-year states that the gross profit on the revenue account for the three corresponding half-yearly periods ending June 30th is: To June 30th, 1912, £5,805. 5s. 7d.; to June 30th, 1911, £6,633. 8s. 2d.; to June 30th, 1910, £4,950. 3s. 6d. The net profit after payment of mortgage interest for the same periods is: June 30th, 1912, £3,349. 2s. 8d.; June 30th, 1911, £4,137. 6s. 9d.; June 30th, 1910, £2,621. 17s. 8d. The balance available at June 30th last, including £330. 5s. 7d. brought forward from 1911, is £3,679. 8s. 3d., and the directors recommend that this amount should be dealt with by paying a dividend (less income-tax) for the half-year ending June 30th, 1912, at the rate of 6 per cent. per annum on the amount paid up on the cumulative preference shares amounting to £2,323. 3s. 1d., and by carrying forward £1,356. 5s. 2d.

A New British Factory for Diesel Engines.—In spite of the progress which has been made by continental engineers in the construction of Diesel engines, it is of considerable interest to note that extensive Diesel engine works are being built at Ipswich by the Consolidated Diesel Engine Manufacturers, Ltd., London. This will be the first large factory in Great Britain devoted exclusively to the manufacture of Diesel engines for ship propulsion as well as for stationary purposes. Situated in a most convenient and accessible quarter of the town, with lines from the Great Eastern Railway running direct into the buildings, the new works will be equipped completely with the latest types of machinery and plant for first rate workmanship. From the inauguration employment will be given to several hundred workmen, and provision has also been made to secure additional land in order to cope with the increasing demand for Diesel engines. All preparations are well in hand, and it is anticipated that the works will be in full swing in the early part of the coming year.

Motor-cars in Canada.—The motor-car is coming into extensive use in Canada, despite the hindrances outside the towns that prevail in the way of poor roads and other obstacles to free locomotion, as will be evident from the fact that no less than 22,000 licenses for motor-cars were taken out in the country last year. The popularity of the motor-car is greater in Western than in Eastern Canada. The bulk of the cars is imported. For the period 1908-11 England supplied 467 cars, of an average value of £260, as against the United States with 5,584, averaging £256 each. The immense superiority of the United States is thus apparent, and it is difficult to attribute the whole of her preponderance in the trade to proximity alone. Motor-cars are also produced largely in Canada by seven or eight companies at most, two of which are native Canadian undertakings turning out a special type of car; the remainder being simply assembling plants in Canada of United States manufacturers which import the various parts from the parent factory.

Boilermakers and the Shipyard Agreement.—It is understood that another ballot of the members of the Boilermakers' Society is to be taken on the question of having a national agreement with the Shipbuilding Employers' Federation. In this case, however, the members are to be recommended to vote in favour of having a national agreement on general questions—such as the fluctuations of wages and also hours and conditions of labour—but that piece-rate questions should be settled locally in the different districts without any appeal to the general national agreement. With respect to the other trades which were signatories to the national agreement from which the Boilermakers' Society have withdrawn, it is understood that they are to propose that this agreement should be amended considerably. They wish to have the machinery for the settlement of disputes speeded up so that there will be a shorter time between the notification of a dispute and its settlement, that there should be time limits within which conferences should be held, after the necessity for them arises; and that in the case of a deadlock, and before either a strike or a lock-out is declared, a further grand conference should be held, presided over by a neutral chairman, with powers, if mutually requested, to settle the point at issue.

American Contract Methods.—The United States Navy Department recently asked for tenders for heavy projectiles for use in the big guns in the American Navy, and although a well-known British firm sent in the lowest tender, it is announced that the contract will be divided amongst several American firms. According to the New York correspondent of the "Daily Telegraph," as soon as it was ascertained that the British bidders were far below every American competitor, representatives of six of the largest steelworks in the United States held a meeting, at which it was declared emphatically that if the Navy Department awarded the contracts to the British company they would never again submit a single offer for American projectiles. This statement was promptly communicated to the Navy Department, who awarded the contracts to American firms. The Navy Department asked for bids on 2,000 14in. armour-piercing shells. The Hadfield Steel Foundry, of Sheffield, England, bid a sum which worked out at £79 a shell. The closest approach to this in the United States was the tender of the Washington Steel and Ordnance Company, which bid £98 a shell. Bids for 3,500 12in. shells showed the same margin in favour of the British company, which bid £37·8 a shell, while the nearest competitor, the Midvale Steel Company, bid £54·8.

British Shipping.—According to the annual statement of the navigation and shipping of the United Kingdom for 1911 just issued by the Board of Trade, the number of vessels on the register in the United Kingdom is returned as 21,072, a decrease of 18 on 1910, and of 117 on 1909, but the tonnage has increased. Those registered in other parts of the empire numbered 18,082, against 17,838 in 1910. The 12,242 steam-vessels registered in the United Kingdom have a net tonnage of 10,717,511, while the 8,830 sailing vessels only aggregated 980,997 tons. There are five steamers, of over 12,000 tons, 22 between 8,000 and 12,000 tons, and altogether 2,430 of over 2,000 tons. The shipping activity of 1911 is reflected in the large number of new vessels added to the register, these numbering 778 with a tonnage of 748,364. Altogether 1,398 new vessels, of 1,107,790 tons, were launched in 1911, against only 1,078, of 698,469 tons, in 1910. Of last year's total 322 vessels, of 193,134 tons, were for foreigners. War vessels launched in 1911 totalled for the Navy 228,123 tons, and for foreigners 8,130 tons. In shipbuilding the Tyne ports (231,377 tons) lead the way, with Glasgow (203,999 tons) second. Including transfers from foreigners and the Colonies, the total additions to the register in 1911 were: Sailing vessels, 198, of 20,641 tons; steamers, 822, of 824,252 tons. Four hundred and fifty one sailing vessels, of 150,130 tons, and 580 steamers, of 549,467 tons,

were deducted from the register. Wrecks or other losses accounted for 128 sailing vessels and 115 steamers, while 86 and 54 respectively were broken up or otherwise destroyed.

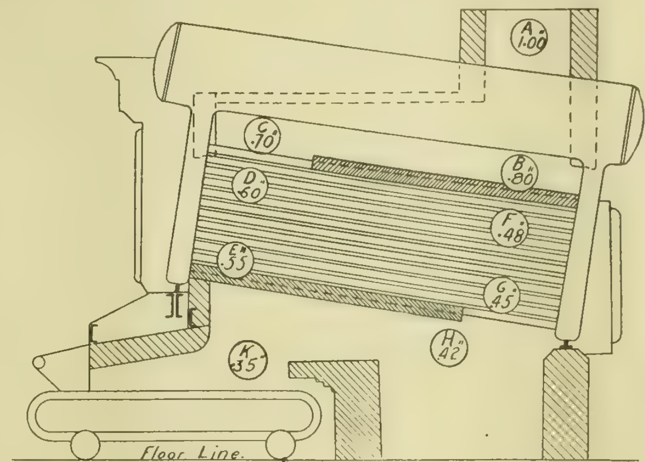
Steel Dumping and the Tinplate Trade.—In the course of a paper on "Dumping, as it Affects the Steel and Tinplate Industries of South Wales," read by Mr. J. H. Jones at the recent meeting of the British Association, the author stated that the relations of the steel and tinplate industries of South Wales had fundamentally changed under the pressure of foreign competition. Before the dumping commenced, tinplate manufacturers always bought their bars. During the iron trade crisis of 1907 and later, Belgians, Germans, and Americans all dumped bars in South Wales. They sold at prices 7s. 6d. to 15s. per ton below those ruling for the home made article. But they proved in reality less desirable than they seemed, even to purchasers. Foreign bars had to be purchased at buyers' risk, and paid for on delivery. They were not suited for makers of odd sizes, and small orders received no notice, since the dumper would send bars only by the shipload. Quality always varied, and at first was very bad. Thickness was not constant; the bars were more difficult to manipulate in the mills, and broke machinery. The quality of Siemens' bars was now improved, but purchasers of tinplates still stipulated for tinplates made from English bars. Another fault of the dumped bars was that delivery could not be guaranteed. The results of the dumping were now apparent. The Welsh bar manufacturers, who used to be unwilling to supply bars except in large quantities and standard sizes, now willingly supplied bars of all sizes and quantities required. Other good results were few. Dumping made the whole industry more unstable. It produced violent and unforeseen fluctuations in the market, and increased the difficulty of contracting for future delivery. In 1905 American dumping ceased for a time, and during the respite the Siemens' Bar Association was formed in South Wales to stabilise prices, though not to restrict output. Its effort to regulate the price of bars was successful till 1907, when the foreign bars again appeared. Then, to preserve their markets, the Welsh bar-makers acquired interests in the local tinplate works. Most tinplate manufacturers had now an interest in a steel mill. The position at present was that though the Bar Association appeared successful and its regulation of prices was observed, steel manufacturers were competing in the next stage as tinplate-makers. The lesson of the whole business was that the dumping pursued by Protectionist countries might and did hurry on the formation of monopolistic combinations in the Free Trade country which was subjected to the dumping. From the dumping process makers and consumers benefited little.

DRAUGHT LOSSES IN A WATER-TUBE BOILER.

THE draught losses in a water-tube boiler, arranged with which is known as horizontal baffling, are referred to by Mr. T. A. Marsh in the current issue of "Industrial Engineering." There are, he states, many features in this baffling which recommend it. It affords a long tile furnace roof, which, in effect, acts similarly to an arch and yet is maintained at a relatively low cost, compared to the sprung or independently supported arch. This firebrick roof formed of tube tile renders the furnace adaptable to smokeless combustion, and by offering a maximum amount of incandescent brickwork makes possible the igniting and burning of certain fuels which could not be used in any other furnace unless equipped with a full Dutch oven. Another feature of this type of boiler baffling is that when broken or burned, permitting a short circuit of hot gases to the chimney, repairs and replacements are easily made, more easily, in fact, than in any other type of boiler baffle. This is important, too, since local conditions often demand special proportions of opening between baffles and headers, and not infrequently, too, different boilers in the same plant may demand special treatment in this regard. All of this is rendered easily possible by the addition or removal of the tube tile. If properly designed, the draught losses through this type of boiler setting are not extreme, and a majority of the most serious cases of draught reduction are easily rectified. The normal draught pressures at various critical points throughout the boiler setting are as indicated in Fig. 1.

From these draught readings, which are averages of numerous series, taken through this type of boiler, the following general statements can be made: (1) There is a loss in draught pressure of considerable moment between the points A and B, where the gases must pass through a somewhat restricted section between the side walls of the setting and the boiler drums. This point of design must be watched closely, and a liberal area must be provided, if high boiler ratings are to be obtained. (2) Under proper conditions, the furnace draught available for fuel burning is approximately one-third of the uptake draught. Therefore, in order to ensure a specified furnace draught, provision must be made for three times this amount in the uptake. (3) The loss through the boiler tubes from D to G is not proportionately large, as the gases passing lengthwise of the tubes do not meet as much resistance as when passing transversely, across the tubes. Knowing this drop in draught from D to G, under conditions of an open damper and tubes free from soot, will give a clue to the condition of cleanliness existing in a given setting.

With this type of baffle, soot accumulations occur on top of the baffles, and care must be exercised daily to ensure clean heating surface. The difference in draught pressures



above and below the baffles is in each case so great that short circuits are thereby invited, and the condition of these tiles must be watched to ensure that no heat is lost directly to the flue. For example, consider the difference in draught pressure between the points K and E, which is sufficient to cause the hot gases and flame to seek the slightest crevice between the tube tile. A similar point occurs between the points F and B, where the difference in pressure is 0·32in., and the condition is even more serious. Compared to a vertically baffled boiler, this type offers a total resistance to gas considerably in excess, as evidenced by the furnace draught being only one-third of the uptake draught in this case, while in the case of the vertically baffled boiler, the furnace draught is one-half of the uptake draught under the best conditions.

The section between the top of the bridge wall and the lower baffle warrants attention. This area should be ample to take care of the maximum volume of gases generated at the highest boiler rating, and the gas velocity should not exceed 35ft. per second. Moreover, since this section is inclined to close up, due to accretions building up on the bridge wall top, a clean-out door should be provided directly over the bridge wall in order that such accretions may be removed during operation, or at least during such time as the boiler is banked.

Knowing the draught conditions as presented to represent proper conditions of gas flow with the boiler setting tight, and with the passes free from accumulation of dirt, the engineer should be able to locate by means of a draught gauge such troubles as dirty boilers, porous fuel beds, air leaks in the settings, restricted baffle openings, and short circuits through the boiler baffles. Frequently troubles will be indicated from the furnace draught alone. This, combined with the uptake, will almost invariably indicate something to one familiar with normal conditions. A complete analysis of the draught, as shown above, ensures that no efforts in rectifying trouble be misdirected, and presents the draught problem in concise and analytical form.

Atherton Boiler Explosion.—The formal investigation ordered by the Board of Trade in regard to the boiler explosion at the Dan Lane Mill, Atherton, will be held in the committee room, Town Hall, Manchester, on Tuesday, October 15th, at 11 a.m.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Machine for milling and boring purposes. Shanks. 13175.
Drills and taps for multiple diameter holes. Walkden. 17756.
Surfaces for the transmission of heat. Knowles. 19280.
Feed water regulators for steam boilers. Trist. 19296.
Driving mechanism for machines. Fish. 19351.
Metallurgical gas furnaces. Tschernoff & Sendzikowsky. 19381.
Hydraulic change-speed gear. Soc. Anon. du Temple. 19452.
Reversible rotary motor. Brun. 19472.
Hydraulic pumps and motors. Carey. 19519.
Valve actuating mechanism for internal-combustion engines. Kieling. 19567.
Apparatus for removing scale from boilers. Schror & Raschen. 19571.
Extraction of zinc from zinc ore. Roitzheim. 19587.
Mechanical hammers. Moessmer & Zimmermann. 19589.
Steam generators. Langton. 19688.
Water gauges for steam boilers. Wheatley. 19692.
Carburetters for internal-combustion engines. Berwick & De Beer. 19740.
Devices for relieving compression in internal-combustion engines. Rowe. 19778.
Rotary force-pump for delivering liquid to several different places. Daimler-Motoren Ges. 19872.
Lifts, hoists, and water-raising devices. Escalada. 20137.
Automatic means for balancing aerial machines. Benni. 20229.
Rocking firebars for furnaces. Neil & Rutherford. 20415.
Combined reciprocating engines and turbines. Wurl. 20449.
Process for the recovery of ammonia and by products in gas producers. Hunt. 20938.
Apparatus for washing or purifying and cooling air and gases. Cole. 21605.
Carburetters for internal combustion engines. Newcomb. 22343.
Flying machines. Short, Short, & Short. 22407.
Internal-combustion engines. Short, Short, & Short. 22409.
Uni directional flow steam engines. Davidson & Larmuth. 22573.
Safety devices for power presses and drop hammers. Jackson. 22911.
Steam engine governors. Eastwood. 23071.
Valves and valve gear for internal-combustion engines. Albion Motor-car Company, and Murray. 24705.
Force pump. Oldham & Oldham. 25735.
Air pumps for use with condensers. Oddie. 25832.
Bearings and lubricating apparatus. Alfred Steel & Sons, Ltd., and Steel. 26395.
Thrust bearings. Cooper. 27465.
Automatic cleansing devices for gas generators. Hart-Bayes. 27688.
Carburetter for internal-combustion engines. Martin. 27784.
Air gas and oil engines. McIntosh. 27882.
Crucible furnaces. Koch. 28567.
Fluid-pressure turbines. Brown. 28731.
Aeronautical machines. Doutre. 29117.

1912.

Process for the extraction of copper and nickel particularly from low-grade ores and products. Borchers & Pedersen. 227.
Safety lamps. Tombelaine. 241.
Speed recorders. Henkle. 656.
Grinding tools. Kirkman, and Robert Warner & Co. 994.
Carburetter for explosion motors. Turcat. 1088.
Pulleys for high speed transmission. Soc. Anon. pour l'Exploitation des Procédés Westinghouse Leblanc. 1459.
Manufacture of inextensible transmission belts. Soc. Anon. pour l'Exploitation des Procédés Westinghouse-Leblanc. 1460.
Fluid pressure braking apparatus. Turner. 2455.
Apparatus for compressing and distributing compressed air under pressure as a motive force. Wilkinson. 3028.
Means for protecting metallic surfaces from corrosion. Lake. 3626.
Sanding apparatus for locomotives. Willans. 4622.
Beater for gratebars of furnaces. Davis. 4641.
Automatically adjusting bearing for connecting rods of engines and fixed bearings. Jacques. 5483.
Automatic lubricators for lifts and elevators. Wetzel & Kuntz. 5961.
Valve mechanism for 4 stroke-cycle internal combustion engines. Jumelle. 6067.
Processes for extracting vanadium from ores. Saklatwalla. 6119.
Two stroke cycle internal combustion engines. Fried. Krupp Akt. Ges. Germaniawerft. 6631.
Patterns for foundry moulding. Pipher. 6742.
Nut-locks. Hawes. 7254.
Turbines. Josse & Christlein. 8814.
Apparatus for heating and superheating purposes. Imray. 9745.
Variable-speed gearing. Schweinfurter Pracisions Kugel-Lager-Werke Fichtel & Sachs. 9965.
Arrangement of engines for propelling ships. Geb. Sulzer. 10240.
Multiple opening balanced slide valves. Andrews. 10522.
Regenerative gas furnaces. Siemens. 10824.
Marine governor. Lawson & Beacroft. 11192.
Means for connecting tachometers to locomotives. Rensch. 11963.
Transmission gears for motors. Lancia. 12493.
Appliances for automatically regulating the injection of cooling water in internal-combustion engines. Moore, and Ambrose Shardlow & Co. 13068.
Centrifugal fans. Siemens Bros. Dynamo Works, Ltd., and Hackett. 14932.

ELECTRICAL, 1911.

Dynamos. Price. 19581.
Telegraphic relays. Brown. 19779.
Quadruplex Hughes printing telegraphs. Banzati. 19845.
Electric safety fuse. Müller. 19856.
Electric furnaces. Bourcoud. 20033.
Collectors for electric traction. Sayer. 20100.
Electric switches. Berry. 20171.
Series electrical lighting. Atherton. 20794.
Electromagnetic relays and electromagnets. Western Electric Company. 20860.
Automatic electrically-governed engine stop-gear. Hinckley and Halliday. 23359.
Magnetic clutches. Collier. 24776.
Means for use in automatically regulating the timing in magneto-ignition apparatus. Diehl. 25161.
Telegraphic systems. Faiella. 27510.
Manufacture of metallic filament incandescent lamps. Siemens Bros. & Co. 29098.

1912.

Magneto-electric machines for ignition. Heyer. 1395.
Electric incandescent lamps. Henderson. 7148.
Electric signalling circuit for train dispatching. Field. 7435.
Devices for ensuring electrical continuity in metallic conduits for electric cables. Waterhouse, and Simplex Conduits, Ltd. 13079.
Automatic telephone systems. Siemens Bros. & Co. 14563.

METAL QUOTATIONS.

TUESDAY, SEPTEMBER 24TH.

Aluminium ingot	80/- per cwt.
„ wire, according to sizes, &c. ......from	102/- „
„ sheets „ „ ...... „	120/- „
Antimony .... £31/-/- to	£32/-/- per ton.
Brass, rolled	9⅛d. per lb.
„ tubes (brazed)	11¾d.
„ „ (solid drawn)	10d.
„ „ wire	9⅛d.
Copper, Standard	£78/17/6 per ton.
Iron, Cleveland	66/9 „
„ Scotch	72/9 „
Lead, English	£23/-/- „
„ Foreign (soft)	£22/10/- „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£8/5/- per bottle
Silver	29⅜d. per oz.
Spelter	£27/7/6 per ton.
Tin, block	£227/10/- „
Tin plates	15/3 „
Zinc sheets (Silesian)	£30/5/- „
„ (Stettin; Vieille Montagne)	£30/12/6 „

The Society of Engineers.—An ordinary meeting of this society will be held on Monday, October 7th, at the Institution of Electrical Engineers, Victoria Embankment, W.C., when a paper will be read on "Town Planning from an Engineering Aspect," by E. R. Matthews, Assoc.M.Inst.C.E., F.G.S.



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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

The Spontaneous Combustion of Coal.

THE spontaneous combustion of coal is a subject of considerable importance, and at one time or another has received a good deal of investigation. As an isolated and somewhat inexplicable phenomenon it has been known for a long time, but attention was first seriously directed to the subject when coal began to be shipped in bulk, and it was found that such cargoes frequently caught fire, especially when voyages were long and made in tropical climates. The serious nature of these occurrences led to the appointment of a Royal Commission in 1875 to investigate the subject, and as a result a good deal of light was thrown on what hitherto had been an obscure phenomenon. Though the researches of the Commission were confined to spontaneous ignition in coal cargoes, outbreaks are not confined to cases where coal is stored in excessively large bulk. They frequently occur in coal bunkers, and as these have shown a tendency during recent years to increase the matter has been made the subject of enquiry by Lloyd's Register, and an interesting collection of facts and data bearing upon the subject generally is embodied in a report recently presented to that body by the Chief Engineer Surveyor and his staff. Although subsequent investigations have shown that some of the conclusions arrived at by the Commission of 1875 were not correct, many valuable facts were collated which showed that both the tonnage of cargoes and length of voyage were important factors. For instance, in 1874 casualties of this kind occurred only in one-quarter per cent. in shipments of under 500 tons. Between this figure and 1,000 tons they amounted to 1 per cent. Between 1,000 and 1,500 tons they were $3\frac{1}{2}$ per cent., and between 1,500 and 2,000 tons $4\frac{1}{2}$ per cent., while in shipments of over 2,000 tons they amounted to no less than 9 per cent. It will be seen that increase in risk rises rapidly with bulk of cargo. The influence of the length of voyage was equally manifested, for it was

found that out of 70 casualties in 1874, no less than 73 per cent. of the total occurred in cargoes over 500 tons while on voyages to distant tropical countries. In the course of the enquiry it was shown that some coals were much more prone to spontaneous combustion than others, and further, that the size of the coal was also an important factor, smaller coal being much more liable than lumps. Ignition nearly always originated under the loading hatches, where the coal loading was liable to be broken and compressed, the large pieces with every fresh tipping tending to run down the sides of the heap to the boundaries of the hold and leave the small stuff in the centre.

There was a difference of opinion as to the precise chemical action which led to spontaneous ignition, but a general feeling was expressed that the moisture, especially in coal containing iron pyrites, was a very active agent. There was also a divergence of views as to whether it was wise or unwise to adopt a system of through ventilation in a cargo. Some advocated that it was, others as strongly condemned it. In these circumstances two of the Commissioners, Dr. Percy, F.R.S., and Sir Frederick Abel, made a separate scientific report which was accepted by the rest of the Commission. These two gentlemen attached special importance to the part played by iron pyrites, a compound of sulphur and iron, which is more or less distributed in nearly all coals, but in greatly differing quantities and with various degrees of uniformity, being in some scarcely detectable by ordinary inspection, while in others it forms more or less conspicuous laminæ of a more or less brass yellow colour. The oxidation of pyrites, which is accelerated by the presence of moisture through the oxygen in the water being brought into more intimate contact, is accompanied by a development of heat, and they considered that this might accumulate to such an extent as to lead to the ignition of the coal through which the pyrites were disseminated. They pointed out also that carbon itself in a finely-divided condition has the property of absorbing large volumes of oxygen, and that this power of absorption is increased with diminishing size of coal owing to the greater surface then exposed. Further that this absorption is attended with development of heat, which, under favourable circumstances, might accumulate until it ended in actual combustion. As regards the question of ventilation, they deprecated "through" circulation of air, owing to the practical difficulties and to the dangers which might arise from imperfect circulation of this kind, as a restricted supply of air might serve to bring a fresh supply of oxygen to dangerously heated coal, and so promote the chemical action it was desirable to avoid. In preference they recommended efficient surface ventilation, to afford facility for removal into the atmosphere of any gases arising from the coal. The investigations of the 1875 Commission, although instructive, left many questions in regard to the causes underlying spontaneous combustion unanswered, and especially the parts played by iron pyrites and moisture.

In 1898 a commission was appointed by the New South Wales Government for the express purpose of settling this question of moisture, and their experiments were conclusive. Two similar wooden bins capable of holding about 250 tons of coal were placed side by side under a common roof and filled with coal of the same character. In one the coal was loaded in an air-dried condition, and in the other wetted by playing a hose on it. Thermometers were placed in each for ascertaining the temperature, and observations were taken at frequent intervals, with the following results: The temperature of the coal—which, it may be remarked, was exceptionally free from pyrites—rose steadily in the dry bin from 122° Fah. (its mean temperature shortly after loading) until after about 60 days it reached 392° Fah. in its central part, when the experiment was stopped in order to avoid an outbreak of fire. On the other hand, in the wet bin the temperature of the central part only rose from 106° Fah. to 138° Fah. in 38 days, after which the temperature decreased. These figures show that wet coal is far less liable to spontaneous heat than dry coal.

The chemical principles involved in spontaneous combustion appear to have been first established by Richters, though to M. Henri Fayol, the engineer director of the collieries of Commentry, belongs the credit of practically demonstrating them by a series of large-scale experiments upon various kinds of coal, under different conditions as to dryness, method of stacking, fineness, air supply, and initial temperatures. At the outset he proved that the heating effect due to the oxidation of pyrites was much less than was thought by the Commission of 1875, such heating effect as does occur being less than that due to the oxidation of the same weight of coal itself. Prof. Threlfall, who has made a special study of the point, states that the heating effect is only one-fourth, and further, that the oxidation of coal is more rapid than that of pyrites; so that in any particular case it would be reasonable to attribute the trouble to the former rather than the latter. It seems clear from all information now available that pyrites play hardly any practical part, either direct or indirect, in the spontaneous heating of coal. M. Fayol's experiments were most exhaustive and conclusive. His first experiments were made to determine the action of air at different temperatures. As a result of these he found that at all temperatures between 25° C. (77° Fah.) and 400° C. (752° Fah.) all kinds of coal behave in the same way. They first lose a part of their weight, and after a certain time enter a second stage in which they more than regain this loss, while with air at high temperatures they enter upon a third stage in which the weight steadily and continuously decreases until, if the temperature is high enough, the coal is completely consumed. These various changes are indicated in the following table:—

	Temperature of the Air.				
	25° C. (77° F.)	50° C. (122° F.)	100° C. (212° F.)	200° C. (392° F.)	400° C. (752° F.)
FIRST PERIOD.					
First diminution of weight.					
Maximum loss per cent.	0·53	0·81	1·50	1·60	—
Time to attain this loss ..	15 days	24 hours	12 hours	1 hour	—
SECOND PERIOD.					
Increase of weight counting from minimum to maximum.					
Total increase per cent...	0·20	0·20	4·70	5	--
Total duration of exposure to air	150 days	150 days	240 days	8 days	—
THIRD PERIOD.					
Second diminution of weight per cent. starting from the maximum weight.					
Loss	0	0	0	30	100
Total duration of exposure to air	240 days	240 days	240 days	240 days	15 to 20 days

It is obvious from these figures that the temperature at which the chemical interaction between the coal and the air takes place has an important influence on its intensity, and

the question arises whether even at so low a temperature as 200° C. incineration would not be complete, given time enough. A test at Commentry seems to show that it would, for some coal crushed to grains and exposed to the action of air at 200° C. for a period of one year showed a loss of weight of 50 per cent. Following these experiments, M. Fayol conducted others which showed that the increase of weight which occurred in the second stage indicated in the table above was due principally to the absorption of oxygen from the air, the slight diminution in weight in the first stage being obviously due to evaporation of superficial moisture in the coal. It remains to account for the loss of weight which characterised the third stage, and to throw light on this tests were made by subjecting coal to a continuous temperature of 400° C. in a closed vessel. Under such conditions it was found to lose only a very small part of its weight, whereas when exposed freely to air it volatilised entirely in a few days without showing any signs of ignition. The absorption of oxygen, which is the active agent in causing spontaneous combustion, must not be confused with the well-known power of absorption of various gases possessed by freshly-made charcoal. The latter, for instance, will absorb 9¼ vols. of oxygen, but this can be driven off by heating without altering the character of the charcoal, whereas coal will absorb as much as 100 vols. and, once absorbed, this cannot be driven off, while the properties of the coal are profoundly altered.

Having determined the precise variation of chemical activity with temperature, the effect of bulk, size of coal, and method of ventilation (*i.e.*, air supply), upon spontaneous heating remained to be considered. With all coals it was found that size or state of division had much influence, and, as might be expected, the smaller the state of division the more easily coal ignited when subjected to temperature. For example, lignite when powdered inflamed at 100° C., gas coal at 200° C., coking coal at 250° C., while anthracite required a temperature of over 300° C. Since the absorption of oxygen by coal is always accompanied with evolution of heat, it will be evident that if this evolution is greater than the loss by radiation and conduction a rise of temperature will ensue, and vice versâ. Some experiments illustrated this. It was found that if coal was preheated to 100° C. and then heated in quantities of about 5 cubic yards, it invariably began to smoke in two days, whereas such heaps would not ignite at all if made with coal at ordinary temperatures. The action of variable air supply upon spontaneous ignition was strikingly shown by placing a conical heap of about 3 cubic yards, heated to 100° C., under a bell which hermetically sealed the coal. Around the bell were two rows of holes, one near the top and the other near the bottom, which permitted of the air circulation being maintained or discontinued, as desired. When all the holes were closed the temperature fell, and after a few hours did not sensibly differ from that of atmosphere. With several holes of both rows open the temperature rose continuously till spontaneous combustion occurred, and by opening and closing the holes alternately the temperature could be modified at will, and ignition brought about either at the centre of the heap or on the surface, as desired. Summarising the results obtained, it may be stated that the time required for a rise in temperature of a mass of coal exposed to air depends on the kind of coal, size of the heap, state of division, initial temperature, and temperature of the surrounding atmosphere. If in small bulk the conductivity of the air and radiation may convey away all the heat produced. If in large bulk the outer portion may protect the centre from the cooling effect of the atmosphere and cause the temperature there to rise, as there will generally be enough air in the heap to produce oxidation, though if the heap is very large and the state of subdivision such as to prevent further access of air, no great increase may take place. The oxidation is, of course, in direct proportion to the surface exposed—the smaller the coal the more susceptible it is to heating, since the surface presented by powder may be a thousand times larger than that of the same weight of large coal. With big pieces little rise of temperature takes place, as the heat developed is carried away by the air circulating amongst them. The conditions most favourable to heating are a mixture of pieces and powder, high temperature, and an air supply just sufficient to furnish oxygen as fast as it can be absorbed.

The bearing of the experimental data upon spontaneous combustion of coal shows that in respect to coal cargoes there should not be any through ventilation, since any attempt to effect it would be impracticable. The surface ventilation now always provided is sufficient safeguard against the accumulation, above the coal, of marsh gas or other inflammable gases, with their consequent risk of explosion when mixed with proper proportion of air. The Chief Engineer to Lloyd's Register, however, questions whether this ventilation, supplemented as it frequently is by the opening of hatches in fine weather, may not, by supplying a limited quantity of air to the body of the coal, tend to promote spontaneous combustion. The best preventive, if it could be carried out, would be to hermetically seal the holds, leaving provision only for the escape of marsh gas evolved during the voyage, though care would have to be taken to thoroughly ventilate the surface and vacant spaces in the holds before discharging cargo, to get rid of any explosive gas. This may seem to involve special precautions and care, but it is no greater than that habitually exercised with vessels carrying petroleum in bulk. As regards coal bunkers, the conditions are somewhat different to those which apply to the holds of coal cargoes, since while being worked it is necessary to have ample ventilation throughout, and amongst the points which marine engineers, in their supervision, need to watch are that in any bunkers in which men are not actually working the lower doors should be kept closed to prevent any current of air passing into the mass of coal, and if any parts of bunkers, owing to the proximity of boilers, or recesses through which steam pipes are carried, are liable to a more than normal temperature, such parts should be stored with large coal only and worked out as soon as possible, as also should small coal which accumulates under chutes, &c. Further, if any coal is left in a bunker it should be trimmed into position when fresh charges are taken in to ensure its being used on the next voyage, as risk of overheating increases with length of time the coal remains undisturbed. Since wetting coal does not, as was at one time thought, accelerate the tendency to heating, but, on the other hand, retards it, it is advantageous for small coal known to be of a fiery nature to be damped when charged into the bunkers. If heating at any part of a bunker is discovered and there is no external source of heat to account for it, the heating will probably be local and in a part where the coal is small. The best method of dealing with such a difficulty depends, of course, on circumstances, but in attempting to obtain access to the heated parts for the purpose of applying water care should be taken to limit as far as possible the air supply, to prevent the heated zone being converted into an actual fire.

BOOK REVIEWS.

Modern Sanitary Engineering, Part I., House Drainage, by Gilbert Thomson, M.A., M.Inst.C.E., Lecturer on Sanitary Engineering in the Royal Technical College, Glasgow. London: Constable & Co., Ltd.; 8½in. by 5¾in.; 266 pp.; price 6s. net.

One of the most important developments in the field of engineering conventionally known as "civil" is that relating to sanitary arrangements. It has been due partly to the growth of population and concentration in urban areas and partly to the more general recognition that all improvements relating to cleanliness and scientific treatment of waste products make for economic progress. Questions of drainage instead of being dealt with in a haphazard fashion by any unqualified plumber or navvy, as they used to be, are now rightly regarded as worthy of the best scientific skill and attention. Evidence of this is shown in the admirable text book under review which, although dealing only with an apparently modest section of the subject, shows how much there is to know and learn and how necessary work of this kind should be supervised by skilled persons. All who are interested in the subject of drainage and the numerous collateral questions connected with it—and such persons include sanitary officials, architects, surveyors, and handicraft workers of most divers kinds—will find in this work an eminently practical summary of best and latest practice, and we have pleasure in commending it to their notice.

* * *

Steam Boilers and Boiler Accessories, for steam users, engineers, and engineering students, by W. Inchley, B.Sc., A.M.I.Mech.E., Lecturer on Engineering at University College, Nottingham. London: Ed. Arnold; 7½in. by 5¼in.; 412 pp.; price 8s. 6d. net.

The field of boiler engineering is a wide one and the treatment of the subject within the limits necessary for its use as a text book somewhat difficult. It calls for dissertations not only on the materials of construction, but close investigation of fuels and combustion, as well as some rather complex questions involved in heat transmission, treatment of feed-water, apart from a multitude of matters relating to the practical working of boilers and their fittings and accessories, such as feed-water heaters, filters, superheaters, &c., as well as information upon the scientific conduct of boiler trials. The author has endeavoured, and, we think on the whole, fairly succeeded in giving a succinct and intelligible treatment of the various aspects of the subject. The treatment is thoroughly practical and fairly free from advanced mathematics, while at the same time it sacrifices nothing in the way of scientific accuracy.

* * *

Forging, Stamping, and General Smithing. A reference book for foremen smiths, managers, and engineers, giving fully-dimensioned drawings, times of making, and finished weights of over 600 common types of mild steel forgings and stampings executed under the supervision of the author, by Benjamin Saunders, practical foreman smith. London: E. & F. N. Spon, Ltd.; 9in. by 6in.; 428 pp. and 728 illustrations; price 21s. net.

The contents of this book are fully explained by the title. It is practically free from letterpress and confined to the collection of dimensioned sketches with bald statements as to their weight and the time and quality of labour spent upon them. As a record of actual work, however, such facts at times are extremely precious to those who have to supervise or estimate the cost of similar work. For this reason every works manager and foreman smith will find it deserving of a convenient place on his office bookshelf, while in the drawing office it will prove not less equally valuable as a convenient record of worked-out details of current practice relating to stationary and locomotive engines, pumps, hoisting tackle, and colliery machinery.

* * *

The Una-Flow Steam Engine, by Prof. J. Stumpf, of the Technische Hochschule, Charlottenburg. London: Constable and Co.; 11in. by 8¼in.; 229 pp. and 250 illustrations; price 10s. 6d. net.

This is purely a monologue on engines constructed for various purposes in accordance with the principle with which the author's name is identified and which has received numerous applications in power plant, both stationary and locomotive. These various applications are copiously illustrated and the relative merits of the Una-flow system fully explained and emphasized, so that, although it does in some ways bear rather the appearance of a trade publication, it constitutes nevertheless a very complete text book on this type of prime mover.

* * *

Practical Mathematics for Technical Students, by E. L. Bates, Lecturer on Geometry at the L.C.C. School of Building, Brixton, London, and F. Charlesworth, Lecturer on Practical Mathematics, South Western Polytechnic Institute, London. London: B. T. Batsford; 7½in. by 5in.; 512 pp.; price 3s. net. Also by the same authors and publisher, "Practical Geometry and Graphics for Technical Students"; 621 pp.; 4s. net.

The most remarkable feature of these two books is their exceeding cheapness combined with the merits of the text and the admirable way in which they are printed and illustrated. The subjects themselves do not offer much opportunity for special novelty of treatment and there are probably dozens of text books which could claim equal merit in this respect. We know of none, however, that give more for the money, and after a scanning of their pages we put them down wondering how it is done. However, here they are on the market and, as the possibility of remuneration to authors and publisher can only be reached on the basis of a big sale, we sincerely trust the enterprise displayed may reap its reward and that technical students generally will appreciate the cheap pabulum that is here provided for them.

BOOKS RECEIVED.

Journal of the Iron and Steel Institute, No. 1, 1912, Vol. LXXXV. Transactions of the Manchester Association of Engineers, 1911 and 1912. Proceedings of the South Wales Institute of Engineers, No. 3, Vol. XXVIII. Mallet Articulated Locomotives, Record No. 72 of the Baldwin Locomotive Works. Institution of Electrical Engineers, Vol. 49, No. 214, July, 1912. Cassell's Cyclopædia of Mechanics, Part 1. London: Cassell & Co., Ltd. Price 3d. net.

OXYGEN IN BRASS.*

BY PROF. THOMAS TURNER, M.SC.

Occurrence of Oxygen.—It is generally recognised by practical men that brass may be spoiled under certain circumstances as a result of oxidation. For example, brass which has been poured at a lower temperature than usual is apt to be inferior, and this is attributed to the entaglement of oxide of zinc in the metal owing to its viscid or plastic character. It is believed that the inclusion of oxide of zinc in this way may be one of the causes which occasionally lead to rapid and irregular corrosion with condenser tubes. When sheet brass is annealed in a reducing atmosphere, dezincification may take place, owing to the volatilisation of zinc; but if the atmosphere is oxidising, a certain amount of oxide of zinc may also be produced in the alloy, and rottenness result. The conditions under which such results are produced do not appear to be well understood, while the manner in which oxygen acts is generally a matter of doubt. The mode of occurrence, influence, and estimation of oxygen in brass is therefore of considerable practical interest.

It is well known that cuprous oxide is soluble in molten copper, with which it forms a eutectic with 3·45 per cent. of Cu_2O. References to standard researches on this subject will be found in the paper recently contributed to this Institute by Mr. R. H. Greaves, B.Sc.† The copper oxide eutectic is visible under the microscope, and can be very plainly seen with samples of copper which are otherwise pure, though the eutectic becomes more or less obscured as the proportion of impurities increases. Zinc oxide, on the other hand, does not appear to be soluble in zinc, nor can either cuprous oxide or zinc oxide be detected by any characteristic appearance in brass of ordinary good quality.

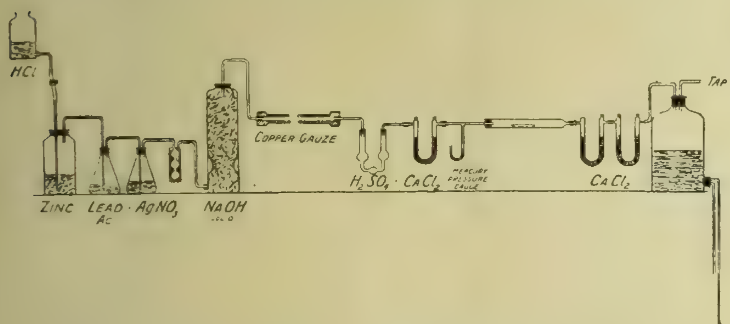
The presence of oxygen has not been recorded in the gases extracted from brass when heated in a vacuum. The question therefore arises as to the form in which oxygen can exist in brass, assuming it to be really present. In order to ascertain whether copper oxide can exist in the presence of zinc, it is only necessary to perform a simple experiment. If powdered

* Paper read before the Institute of Metals, September 26th, 1912.
† "Journal of the Institute of Metals," No. I., 1912, Vol. VII., p. 218.

black oxide of copper be mixed with finely-divided zinc in equivalent proportions, and heated in a test tube, it will be found to react readily with the evolution of heat, and the product consists of metallic copper and oxide of zinc.

The converse experiment of heating zinc oxide with finely-divided copper has been carefully tried in my laboratory by placing the mixture in a porcelain boat in a vacuum and heating to the melting point of copper. If any reduction occurred there should be a corresponding loss of metallic zinc by volatilisation, but our experiments show that no appreciable loss occurred. Hence, though zinc reduces copper oxide to metallic copper when the materials are heated together, copper does not reduce oxide of zinc.

From this it is evident that copper oxide cannot possibly exist dissolved in brass, as it would be immediately decomposed when the alloy was melted. The only oxide which can exist would appear to be oxide of zinc, and this might conceivably be either in solution or in suspension. So far as I am aware at present, there is no evidence to prove that oxide of zinc can



dissolve in brass any more than that it can dissolve in zinc itself; nor is there any microscopic evidence of the separation of oxide of zinc in brass either as a eutectic or in any similar form. We are driven, then, to the conclusion that any oxide of zinc that may be present is mechanically entangled, and when it has any effect upon the microscopic structure it is represented merely by minute holes, in which it originally occurred, but from which it has been removed during the processes of polishing and etching.

Estimation of Oxygen.—The usual method of estimating oxygen in copper is that introduced by Archbutt,* in which the sample is heated in a stream of hydrogen, with suitable precautions, and the oxygen is determined by loss of weight of the copper. Some analysts prefer to weigh the water produced by the reduction of the copper oxide. The "difference" method is simpler and quite satisfactory so long as there are no volatile impurities. The temperature required is only a low red heat. Oxide of zinc, on the other hand, is infusible and non-volatile in an oxidising atmosphere at ordinary furnace temperatures. The temperature of reduction of ZnO is high, varying somewhat with the pressure and with the nature of the reducing agent. It is approximately 1,000° C., or, say, 50° to 100° above the boiling point of zinc. Hence any oxygen present as oxide of zinc cannot be directly estimated by loss of weight on heating in hydrogen, as a quantity of zinc would be volatilised when the oxide was reduced. Attempts have therefore been made to determine the oxygen in brass by means of the weight of water produced on heating the alloy in hydrogen. For this purpose a drying tube has been employed, and weighed before and after the experiment.

As there was reason to believe that such a method was unsatisfactory, the reaction has recently been re-investigated in my laboratory by Mr. R. W. D. Nevill, B.Sc. The apparatus employed is illustrated above. It will be seen that hydrogen, which was obtained by the action of dilute hydrochloric acid on zinc, was purified by being passed successively through lead acetate, silver nitrate, and caustic soda. In order to remove any trace of oxygen the gas was then passed over heated copper gauze and through two drying tubes, to absorb any water produced from the trace of oxygen. The hydrogen then passed through a hard-glass combustion tube, the end of which was drawn out so as to avoid the use of a rubber bung connection with the drying tube and aspirator. The material to be tested is placed in a porcelain boat and is heated to redness with the aid of a small combustion furnace. The hydrogen, after passing through the combustion tube, was dried, and any increase of weight of the drying tube carefully noted. The second calcium chloride tube, shown in the figure, is a guard tube to prevent diffusion from the aspirator. The aspirator is furnished with a water manometer which is graduated in half-litres. By allowing water to enter through the tube from the water tap, or by drawing water through the bottom tube, the pressure in the aspirator can be normalised, and thus the quantity of gas passed can be read from the graduations. Blank experiments were first conducted, in which hydrogen was passed through the apparatus so as to clean out any air, and then 4 litres of hydrogen were passed through the drying tube, which was always weighed when full of hydrogen. The weight of the drying tube was found to be the same after the experiment as before, thus showing that the drying tubes were effective. In order to test the hydrogen for any trace of oxygen some copper strip was taken, and was first heated in a glass tube in the hydrogen for about six hours, to eliminate the whole of the oxygen originally present in the copper. A weighed drying tube was then inserted, and 4 litres of hydrogen were passed, after which the tube was removed and again weighed. As a result, a regular increase of 0·0026 gramme was recorded. This increase was apparently due to a small quantity of oxygen not removed by the copper gauze. A plug of platinised asbestos and a further length of copper gauze were then introduced, when it was found that 4 litres of gas only caused an increase in weight of 0·0002 gramme in the drying tube, and this was considered satisfactory.

Some brass turnings weighing 9·2203 grammes were then substituted for the copper strip, being placed in a porcelain boat in the combustion tube. On expelling the residue of air and heating the brass turnings for 90 minutes in a slow stream of hydrogen, it was found that there was no increase of weight in the drying tube. There was, however, a ring of oxide of zinc formed at the edge of the zinc sublimate contained in the tube. These experiments showed that oxide of zinc might be in the metal in the heated portion of the combustion tube without any corresponding quantity of water being obtained. Experiments were next conducted with pure oxide of zinc, which was placed in the boat in the combustion tube, and heated to temperatures increasing up to 1,000° C. It was found that there was no increase of weight of the drying tube, though a quantity of oxide of zinc was condensed on the sides of the combustion tube. The origin of this zinc oxide appears to be as follows:—

The hydrogen reduces zinc oxide to metallic zinc, which volatilises together with the water produced by the reaction. The water oxidises the zinc vapour as the temperature falls, and reproduces oxide of zinc and hydrogen, the net result being that no water is carried away to be absorbed by the drying tube. This is in accordance with the observations of St. Claire Deville and also of Dick. The former observed that when zinc oxide was reduced by hydrogen, if the gaseous velocity was small, the zinc formed was nearly all reoxidised; but that with increased velocity of the hydrogen the proportion of metallic zinc obtained is greater. Mr. Nevill therefore proceeded to try experiments dealing with the effect of increased velocity of hydrogen, quantities up to 1 litre per minute being employed. Zinc oxide was heated in a porcelain boat to a high temperature, as before. A considerable proportion of zinc oxide was reduced, and metallic zinc volatilised. The proportion of zinc was certainly much greater than with a slow stream of gas, but even with this excessively quick rate of passing the gas there was still a fringe of oxide on the sides of the tube.

It is therefore evident that no accurate determination of oxygen in brass can be made by adopting the methods which are suitable for copper. The volatilisation of zinc from the sample when heated in hydrogen renders the loss of weight quite untrustworthy as an indication of the oxygen removed; while the secondary reaction, whereby zinc vapour is oxidised by water vapour as they pass together out of the heated portion of the tube, prevents more than a small proportion of any oxygen which is present from being absorbed as water by the drying tube. Methods of extraction of oxide of copper by digestion of brass turnings in ammonia are evidently quite untrustworthy, as there is reason to believe that copper oxide is not present in brass, and anything which is extracted is obtained merely as a result of errors in manipulation. A description of a simple and direct process for the accurate determination of oxygen in brass would be appreciated by many who are interested in the subject.

* L. Archbutt, "Analyst," 1900, Vol. XXV., p. 253; 1905, Vol. XXX., p. 385.

A NEW TYPE AND METHOD OF CONSTRUCTION OF LARGE GAS ENGINES.*

BY ALAN E. L. CHORLTON, M.I.M.E., A.M.I.E.E.

THE theoretical economical advantages of large gas engines as prime movers are so well known in this country, particularly when using the waste gases from either blast-furnace or coke ovens, that some explanation must be sought to explain the relatively slow progress which has taken place in their use when compared with that on the Continent, especially in Germany. The importance of these economies, as affecting cost of production, is probably greater for the iron, steel, and coal industries than for any other, and is of such obvious moment that the disadvantages of the gas engine that are held to exist in this country as compared with Germany must be of very real significance indeed to in anywise account for the relative small extent of their usage in these industries. This situation may have been brought about by one or other of two quite different causes, or a combination of the two: (*a*) The usually credited disadvantageous characteristics of the gas engine itself; or (*b*) the reduced first cost and peculiar applicability to existing installations of its most formidable competitor, usually the steam turbine of the mixed-pressure type.

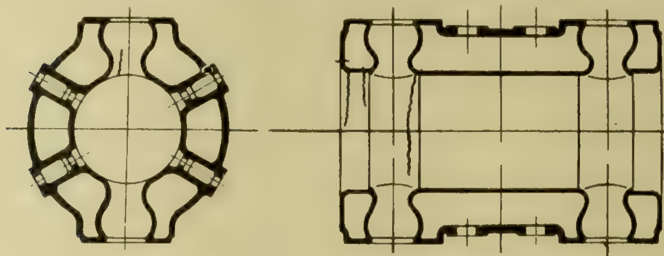


FIG. 1.—FOUR-CYCLE CYLINDER, SHOWING CRACKS.

What are these characteristics of the large gas engine which have restricted its progress? It is to be feared that they are still, to the general industrial mind in this country, as follows: (1) Not fully reliable. (2) High in first cost and installation. (3) High in cost of upkeep. (4) Developed and brought into greatest use abroad.

Whilst the steam turbine: (1) Was invented and developed in this country. (2) Is cheaper to install when steam boilers, &c., are already in use, or exhaust steam available. (3) Is considered more reliable. (4) Is reputed to have a lower cost for repairs and upkeep. (5) When of the exhaust type enables much old plant to be retained in use, while still effecting considerable economy.

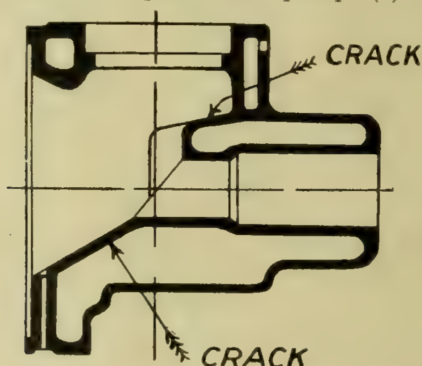


FIG. 2.—TWO-CYCLE HEAD, SHOWING CRACKS.

It is not the object of this paper, however, to enter further into this comparison, but merely to consider it as affecting the question of the large gas engine from the point of view of design, cost, &c. The limitations which have prevented the progress of the large gas engine will be seen to be primarily due to (*a*) the prevalence of the belief of unreliability, (*b*) the comparatively high total first cost of installation.

Unreliability.—This view of unreliability has, of course, been formed from the troubles experienced in the past, though it has been actively combated by various engineers when referred to present types. It may be said, constructionally, to refer to the cracks and breakages of important parts of the engine (undoubtedly a too common occurrence in the past). To briefly illustrate this, as it materially helps the raison d'être of the new design to be followed, figures have been prepared, showing the cylinders and cylinder heads as formerly made of the large-type engines, and as they are now manufactured in attempting to overcome this liability.

Generally these troubles sprang from initial foundry strains set up between the inner and outer walls of the casting when these were cast in one piece, as was the original practice. These initial strains, augmented by those set up through the different temperatures of the parts when working, eventually caused cracks and failures. Fig. 1 shows a cylinder of the old type (4-cycle) with some cracks indicated. Fig. 2 shows similar cracks due to the same cause in cylinder heads (2-cycle). This more than ordinary occurrence of cracks compelled makers first to discover the reason, and then to amend their designs to prevent them; and the final forms of all types had the inner and outer skins of metal connected only as far as possible in one place, the other ends being left free to allow all the differential expansion and contraction set up in the foundry and in working to take place freely. A flexible connecting membrane completed the jacket to retain the cooling water in place.

Figs. 3 and 4 show cylinders and cylinder heads of the later designs, in which it can be seen how greater freedom was allowed. If possible, still further improvement was desirable to dispose of the awkward shapes round the valve pockets, &c., and to do away with the connection between the jacket and the inner wall at A (Fig. 3), where cracks also had occurred, quite apart from any troubles which might occur with the valves themselves; in fact, it was preferable that the jacket should be entirely dissociated from the cylinder in casting, a further reason being that different mixtures of cast iron were required for the conditions which the parts had to meet during service. From the practical point of view, it appears that the cylinder should have no valve pockets, that is, it should approximate to a simple pipe, and that the jacket should be a separate casting. The next source of unreliability is in the valves and valve gears, subject to the heat and stress of the explosion. This is a frequent cause of failures for all prime movers. Obviously, therefore, an improved engine should, if possible, (1) be valveless, (2) have cylinders of simple pipe form, (3) have separate jackets.

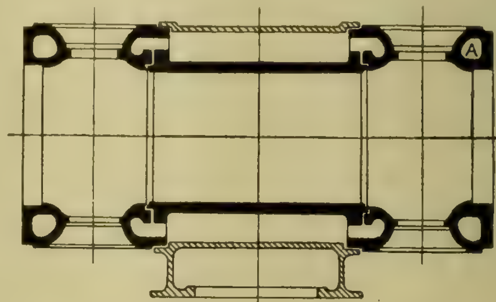


FIG. 3.—PRESENT DESIGN OF CYLINDERS AND HEADS.

The only large engine with cylinders of pipe form without valve pockets, &c., and where the two pistons performed the various valve functions successfully, was the Oechelhäuser; the disadvantages of this type, which have restricted its use, although its thermal economy is well known, spring from other causes, as high first cost, large floor area covered (horizontal type), &c.

The success of a valveless action was confirmed by the author's English experience with the working of the central exhaust ports by the piston in the Körting type engine—an experience which clearly indicated that there was no apparent reason why the air and gas inlet to the cylinder should not be controlled by a similar method in an adjacent cylinder. The outcome of this was the adoption of two parallel cylinders with ports about the middle, connected by specially shaped passages at their ends; one piston thus controlling the inlet through the ports in one cylinder, and its fellow expelling the exhaust through a similar set of ports in the other cylinder. This design was more or less bound to be of the 2-cycle type, and he naturally leaned to such a principle, seeing that his

* Abstract of paper read before the Iron and Steel Institute, October, 1912.

experience had convinced him that by retaining, amongst other things, small cylinder diameters, it was the most suitable form for large powers. A somewhat similar type of cylinder had already been known in the single-acting form for small motor engines for a number of years, but it had not been adapted to large powers nor made double-acting in the special form the author now presents it.

From the section Fig. 5 of the cylinder it will be seen that it consists of two single-walled "U" tubes placed end to end, the inlet and exhaust ports being about the joint; flanges on the cylinders—set back somewhat from this juncture—hold in between them the exhaust and inlet boxes. The whole cylinder unit presents extremely simple forms of single walled castings, particularly suitable for successful and economical foundry work without setting up casting or expansion strains, and also for use in internal combustion work itself, as there are no pockets or irregular shapes; all sections are more or less cylindrical, including the connecting passages. No heavy flanges or joints occur about the points of maximum pressures and temperatures, as in the ordinary type of engine. This form gives most effective cooling to all parts, as, being inherently of a strong section, they can be made with comparatively thin walls. The efficiency of the cooling is further increased by the accessibility of the water to all parts of the combustion chamber, the usual thick flanges and joints there being avoided. Thus, the engine may run at a higher temperature than is usual in the present large sizes. In fact, on test, full load has been maintained continuously with the jacket water boiling, and under such conditions the amount used can be considerably reduced (allowing in some cases the motor-car type of cooler to be used with its advantages of small space occupied, &c.). Further, the absence of joints and cavities in the combustion chamber reduces the risks of pre-ignition, and improves the efficiency of scavenging. High compression can be used without the disadvantages of water injection.

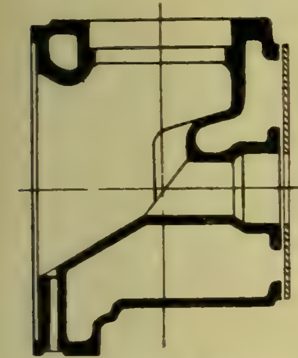


FIG. 4.—PRESENT DESIGN OF CYLINDERS AND HEADS.

All the cylinder, &c., walls being single, the jacket must be provided in a suitable manner to retain the necessary water, and this is most readily done by dropping the whole duplex cylinder into a simple tank, the cylinders resting by their central flanges on stools on the tank bottom or engine entablature. By this construction is secured at once complete allowance for temperature expansion without restraint; the exhaust outlet, the only connection to the outside, passes through the tank wall by a stuffing box, or a flexible membrane is used, the connection to the charging pumps being within the jacket tank. In casting complete expansion is allowed in all directions, and no strains are set up, all the cylinders, &c., being single walled. Difficulties with valves are done away with, for though these are now much rarer than in the past, still the exhaust valve of all 4-cycle engines remains a part requiring considerable attention. No doubt the present large horizontal gas engines, with their simplified valve gear, are a great improvement over the previous types; still, the further great advantage of an engine with no valve gear must be apparent, particularly when taken into account with the possibilities of higher rotational speed. There still remains the disadvantage of heavy capital outlay when the present large engine of the horizontal type is considered.

High First Cost.—It having now been shown how in the duplex design the unreliable parts of the gas engine are effectively dealt with, it remains to meet the other objection to horizontal type gas engines of large power, *i.e.*, high first cost of installation. The cost if installation of a gas central station primarily consists of: (1) Engines; (2) flywheels; (3) electric generators; (4) foundations; (5) buildings; (6) crane; (7) switchboard and cables; (8) auxiliaries, &c.

The first six items are probably the possible variables, and so will be considered in order: (1) For large powers the present comparatively slow-speed horizontal engine is the only one in the field, and the large amount of room taken up by this type, with its expensive foundations, &c., is well known. The cheaper prospect, judging from steam usage, and some work already done in medium-powered gas engines, is in the vertical design. Again, judging from steam practice, a high-speed forced lubrication closed-in type, particularly for electrical work, is the most successful; incidentally, the oil from the same system may be used for piston cooling, as is now standard practice in Diesel engines. It seems necessary, therefore, that the engine should be vertical high-speed enclosed with forced lubrication, for by it (2) flywheels are greatly reduced in size, weight and price; (3) generators are less by about 50 per cent.; (4) foundations being a simple block are cheaper by a like ratio; (5) buildings, owing to the small floor space taken up, are greatly decreased in size; and (6) the crane is of less span, and probably has to lift a much less maximum weight.

As the vertical duplex type runs at twice the speed of the present horizontal, and if the cost of the engine itself is not taken at a lower rate, although it seems reasonable to suppose that it might be, we get a comparative table of costs per brake horse-power as follows:—

	Horizontal.	Duplex.
	£	£
Engine...	5·00	5·000
Flywheel	0·50	0·200
Generators ...	2·00	1·000
Foundations	0·35	0·175
Buildings / Crane	1·00	0·675
Totals ...	£8·85	£7·05

These figures are comparative only, and might be taken on a lower basis. The reduction in cost, however, effected by installing the large vertical "Duplex" type as against the present horizontal engine is 20 per cent. If the engine is taken at £4·5 per brake horse-power the gain is 26 per cent. The floor areas for stations containing horizontal and "vertical duplex" engines of equal powers (10,000 b.h.p.), including switch-room, are respectively 16,916 sq. ft. and 10,756 sq. ft., showing a gain of 36·5 per cent. in favour of the vertical.

A brief general description of the improved type of gas engine derived from the foregoing would be: The engine is of the vertical type, very similar in a general way to those steam engines now so much in favour in this country. It works on the 2-stroke cycle. All working parts are enclosed, and the lubrication is by oil under pressure from a direct-coupled rotary pump. The engine may thus run at considerably increased rotational speed, and from the fact that there is a compression on each stroke of the two-cycle engine balancing the inertia of the reciprocating parts, a higher piston speed than is usual can thus be adopted with the attendant thermodynamic gain. The cylinders are of the "Duplex" valveless

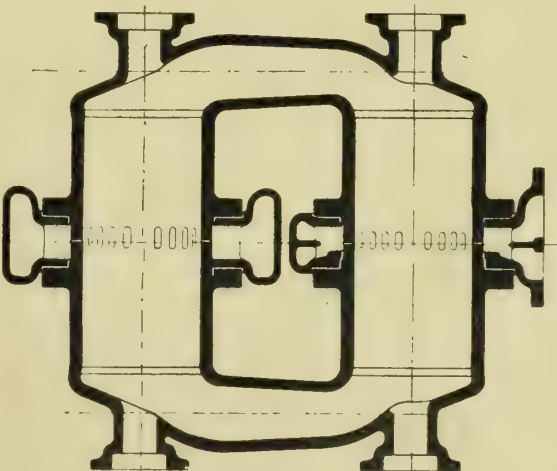


FIG. 5.—SECTION OF CYLINDER UNIT; "DUPLEX" GAS ENGINE.

type, supported about their centres, and free to follow the various temperature expansions in every direction. The necessary water cooling jacket is provided by the cylinder being placed within an ordinary cast-iron tank, and where the exhaust branch passes through the tank side a flexible connection is provided. Ordinary air and gas-charging pumps, driven by an auxiliary eccentric, are provided at one end, within or alongside the tank, and connect direct to the inlet valve-box of one cylinder. The "Duplex" power cylinder is so arranged that the exhaust piston has a lead over the inlet piston. The governor is gear driven, and acts on a simple control valve on the pumps. The ignition is of the rotary magnetic high-tension type in duplicate. The other details of the engine construction are similar to standard high-speed steam engine practice.

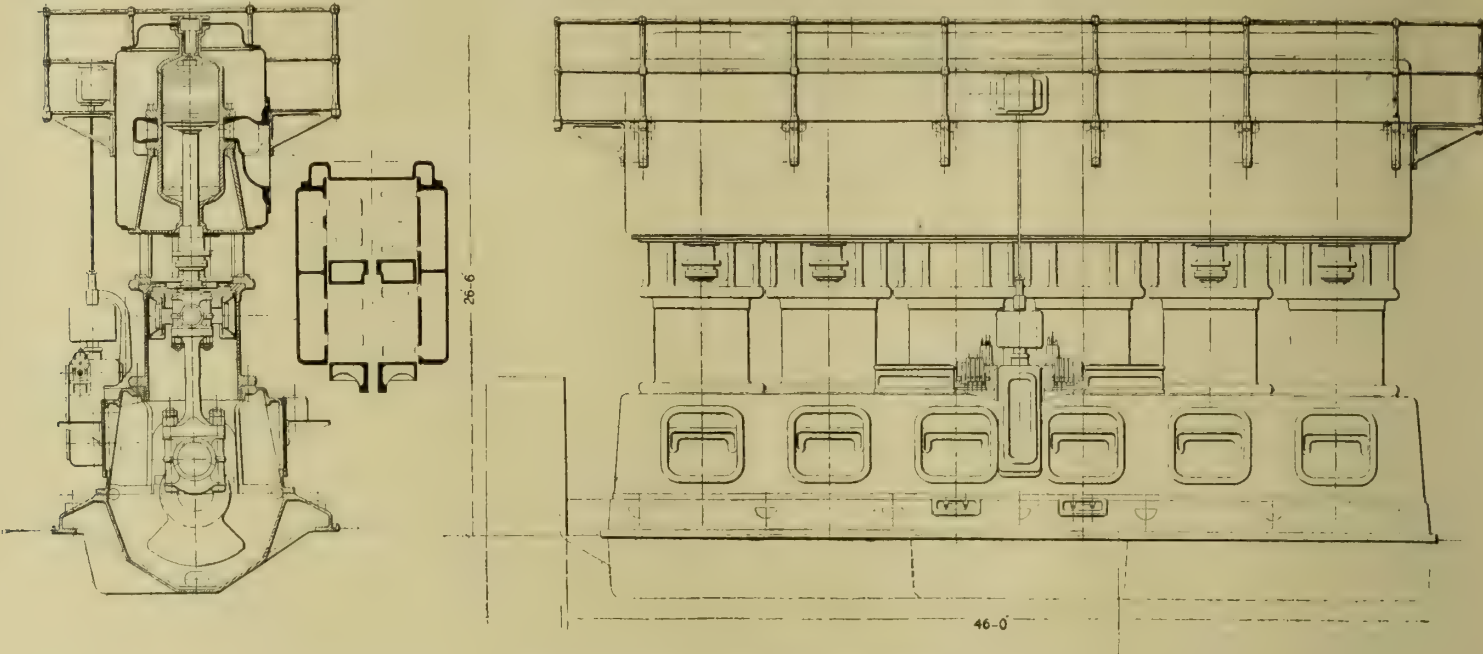


FIG. 6.—6,000 B.H.P. TWIN DUPLEX GAS ENGINE.

In order to indicate the large powers for which these engines can be built, the cylinder dimensions of a vertical twin "Duplex" of 6,000 b.h.p. may be noted (Fig. 6). These cylinders are but 36in. diam. by 43in. stroke, and the speed of revolution 140 per minute. The flywheel is 12ft. 3in diam., and 60 tons in weight, and the floor space taken up by the engine is 475 sq. ft. It must be obvious that these sizes are by no means the limit, and the author sees no reason, from his experience, and what has already been done in other engines, why cylinders of 48in. diam. should not be successfully used. It is interesting to note that a triple "Duplex," with 48in diam. cylinders, and 4ft. stroke, running at 125 revs. per min., would give about 16,000 b.h.p. at quite a moderate mean pressure.

The simplicity of the engine is illustrated by the following table of moving parts under explosion stress for engines of equal turning moment, "Duplex" and 4-cycle horizontal:

Comparison of Main Parts under Explosion Stress of a 4-cycle Horizontal and a Vertical Duplex Engine with Equal Numbers of Impulses per Revolution.

Twin Tandem Four-cycle Horizontal.		*Twin Duplex Two-cycle Vertical.*	
Cylinders	4	Two duplex	4
Pistons	4	Pistons	4
Inlet valves	8 with gear.	Inlet valves	None.
Exhaust valves	8 ,,	Exhaust valves	None.
Piston-rod packing	8	Piston-rod packing	4
Total	32	Total	12
Total moving parts subject to heat stress—20.		Total moving parts subject to heat stress—4.	

It will be apparent that this type of engine, being of such a simple form, is particularly suitable for ship propulsion work, as it can be easily made reversible. Fig. 7 shows a single duplex of the vertical open marine type, another form of which has twin duplex cylinders, with the charging pumps at the back worked by rocking levers from the main cross-heads, as is the common practice with marine air-pumps, though it may be preferable to separately drive these auxiliaries, *i.e.*, the supply or charging pumps, as is now quite common in large steam practice.

It is useful to consider how the conclusions so far drawn agree with, or at any rate are not incompatible with, the thermo-dynamic desiderata, &c., as observed by others. It is, therefore, interesting to give here the opinon of M. Mathot, the well-known authority, on the principles that engine builders should follow in further improvements in their designs, and to see how these agree with the foregoing conclusion and with the principles of the design to be described later.

(1) To produce a system of governing of practically constant ratio of mixture admitted in variable quantity without involving a vacuum in the cylinder.

(2) Increased compressions facilitated by water injection, for example, in such a way as to permit the utilisation of the poorest possible mixtures to burn slowly, but completely, at the commencement of the expansion period. In this way the mean pressure would be increased, permitting the reduction of cylinder dimensions and avoiding sudden explosions, which would be replaced by combustion at nearly constant pressure during a certain period of the power stroke.

(3) Automatic expulsion and complete scavenging of burnt gas, in order that the quality of the following charge of explosive mixture should not be unfavourably influenced.

(4) Design of parts to allow free expansion of the portions in contact with hot gas, so as to permit engines to be worked at higher temperature, and to increase the thermal efficiency by recovering a portion of the heat lost to the cooling water.

(5) The design of details to permit automatic regulation of cooling water circulation in proportion to the work developed by the engine, so as to improve the efficiency under low loads.

(6) The creation of vertical types of large power, both for marine and for industrial services, in order to reduce the space required, and so as to lessen the hindrance with regard to free expansion now existent in connection with the larger tandem horizontal engines.

(7) A practical means of recovery of waste heat from the exhaust gas.

In passing now to the design evolved from the author's somewhat considerable practical experience in the use of the large gas engine in England, the general agreement with these suggestions of M. Mathot will be noted. (1) Calls for a system of governing with a constant ratio of mixture, &c., and is exactly the method employed in 2-cycle engines with separate gas and air-charging pumps of correct proportionate

volume; the mixture, when delivered, being always of that proportion. The "Duplex" engine is of this type. (2) Increased compression and economy is made possible by the pocketless form of the cylinders, thorough scavenging, and effective cooling. (3) Scavenging is, as usual, in 2-cycle engines, done by an air pump at about 4lbs. pressure. (4) Free expansion of all parts is completely provided for as described. (5) Control of cooling water temperature may be readily effected by the governor. (6) The "Duplex" is of the vertical type. (7) Recovery of waste heat from the exhaust.

The latter, though not strictly germane to the subject of this paper, is an interesting part of the internal-combustion engine problem, and one in which the author has had considerable experience with large horizontal engines of the 2-cycle type. The results obtained in the way of evaporation with this type, where the proportion of heat discharged by exhaust to jacket is greater than that of 4-cycle engines, have been as high as 3lbs. per brake horse-power hour, the boiler being fed with hot feed from the jackets and economiser pipes. The steam generated in these boilers can be used in various ways. When the source of the gas is an ammonia recovery producer plant, all that is evaporated will be required for the producers to keep the temperature down.

It is interesting to note that the value of the steam generated, 0·02 pence per brake horse-power hour, is equivalent to the value of the gas taken by the engine with the present price of by-products; thus the gas engine need not be debited with the gas used, and consequently the cost per brake horse-power hour generated is extremely low. On electro-chemical work, with 100 per cent. load factor, the net cost of energy for a 3,000 b.h.p. plant is 0·047 pence per brake horse-power hour, assuming interest and depreciation at 10 per cent. In

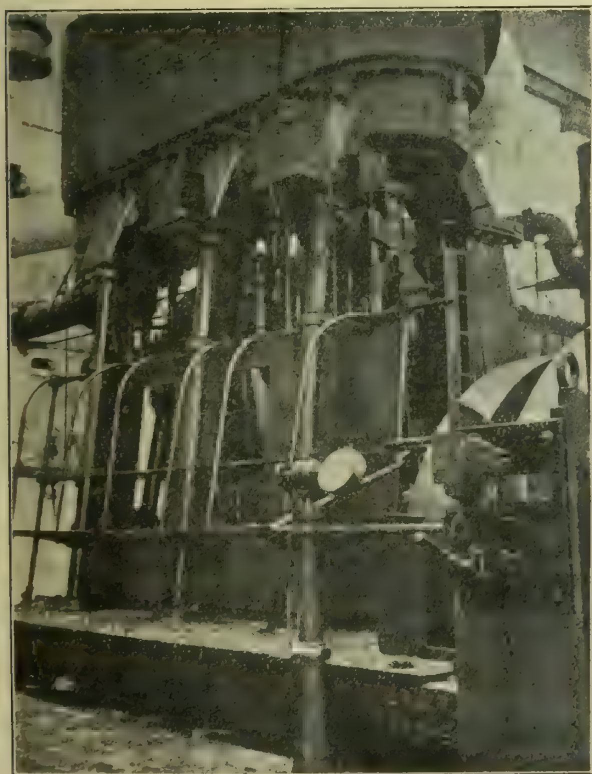


FIG. 7.—VIEW OF MARINE-TYPE "DUPLEX" GAS ENGINE.

other cases the steam can be used for power purposes, driving a steam auxiliary cylinder on the main engine. Or it may be used for any auxiliary plant, as water pumps, or charging pumps, when these may be separately driven. These exhaust boilers act as very effective silencers.

A standard high-speed engine of the vertical "duplex" type, upon which very exhaustive tests have been made on the shop test plate, gave the following figures:—

Mechanical efficiency ....85 per cent.
Heat consumption per brake horse-power..10,500 British thermal units.
Water consumption per brake horse-power ....4 gallons.
Oil consumption per brake horse-power...0·0004 gallon.
Governing ....1½ per cent. rise full load on and off—steady afterwards.

These results are from cylinders 15½in. diam. by 18in. stroke, and will doubtless be improved upon with larger cylinders and further refinements.

The author thinks that he has now briefly but sufficiently described this new type of large engine. So far the experience with it has not been very extensive, but with a full knowledge of what gas engines with their troubles were in the past, he is happy to say it has been uniformly successful; in fact, the first engine built was running on load in parallel with other gas sets within two hours of its first starting up on gas, a result with a new type gas engine he is inclined to think is without precedent.

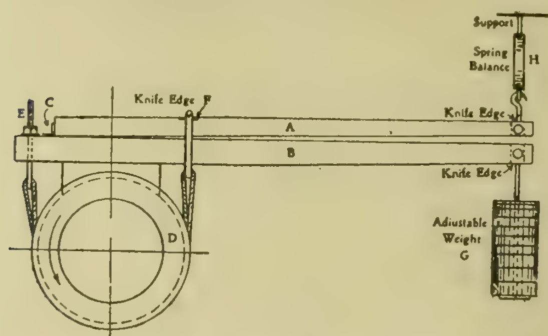
THE USE OF ELECTRICITY IN MINES.

AT the recent annual meeting of the Association of Mining Electrical Engineers held at Sheffield, Mr. W. C. Mountain, of Newcastle, in the course of his presidential address, said that there was in this country a very large amount of good continuous-current machinery running in collieries, and he knew that there was a feeling amongst the owners of such plant that it was looked upon with disfavour by the Home Office. He was satisfied that this feeling was not justified in positions where it was safe to run electrical machinery at all, and he thought he might go so far as to say that the Home Office authorities had no intention of preventing its use or even extension where circumstances permitted or rendered it desirable. He felt confident that in modern collieries, where there was no waste heat or power available, such as from blastfurnaces or coke ovens, the combination of steam winding with exhaust steam turbines would be found much more economical than putting down large generating plants and attempting to adopt electric winding. Even if power were available from a power company for large winding units, it would be found cheaper to adopt this combination than to purchase power at any price at which it would be possible to supply it with any profit to the power company. There was no question that as regarded power consumed, and also the cost of operation, particularly as regarded the wear and tear of ropes, tubs, &c., the endless rope system had many advantages. The recent legislation in connection with the use of electricity in mines, and also the action of the miners themselves, had for a time checked the progress of electric coal-cutting, but he was satisfied that it was only a temporary matter, and that in places where electrical machinery could be safely run, the electrical coal-cutter had many advantages over the older compressed air machine. If they were forced to use compressed air where electricity could be safely used, every coal-cutter worked in that way would cost the owners about £300 per year extra, which would be a heavy handicap on the coalowners, and, of course, tend to increase the price of coal, and thereby injure the worker. In regard to the new rules for the installation of electricity in mines, their main object and intention was, he observed, unquestionably to make armouring compulsory in the future.

Proposed Tower and Bridge to Span the Rhine.— A proposal has been put forward for constructing a tower and bridge to span the Rhine. The tower is intended as a monument to the supremacy of the German iron industry in the world's markets, and has been projected upon a scale that exceeds the dimensions of the Eiffel Tower. Its height is to be 1,625ft., and a platform is to be made 162ft. from the top. In connection with the tower a new bridge is to be constructed across the Rhine suitable for tramway traffic, the bridge to run transversely across the base of the tower. The locality suggested for the structure is the region of the Rhine near the Golzheimer Heath at Düsseldorf. The bridge is to have two arches, each 634ft. wide, and the tower is to rest upon two pillars in the river situated likewise at a distance of 634ft. from each other and in a straight line with the centre pillar of the bridge.

AN IMPROVED DESIGN OF PRONY BRAKE.

No method of testing small motors directly by measuring electrical power intake and mechanical power output is as popular as that by Prony brake, inasmuch as this method gives data from which results are easily and quickly calculated. The Prony brake of the ordinary form consists of a band of some sort which is attached firmly to a single brake arm on one side the motor pulley, passes round the pulley, and is attached to one end of the arm through some adjusting screw by which the tension on the band can be regulated. The other end of the arm rests on a scale, the motor being driven in such a direction that the arm bears down on the scale and registers the weight applied, from which, knowing the motor speed and pulley diameter, the brake horse-power of the motor may be calculated. When the brake is of the above form it presents several bad features. One of these is the impossibility of maintaining a constant given load for any appreciable length of time. If the pulley heats up slightly it expands, binds the band on the pulley, and increases the load; or the constant vibration of the arm may loosen the tension of the band and decrease the load. Such a brake, therefore, needs constant attention in order that the proper load may be maintained. This in itself is a disadvantage, but of far greater import is the fact that as the operator's hand is almost constantly on the adjusting device, the load registered by the balance is not correct, and in case of small motors the error may amount to quite a large percentage. In an article in the "Electric Journal" Mr. E. W. Henderson describes a brake somewhat after the fashion of the Prony brake, but which it is claimed



IMPROVED DESIGN OF PRONY BRAKE.

eliminates the bad features of the latter without losing the simplicity of calculation.

The brake arm is double, as shown in the illustration. The upper part A is hinged to the lower part B at C. The point C should be as far as possible from the centre line through pulley D, and the hinge is therefore located as near the end as possible, allowing convenient room for the adjusting screw E. One end of the rope or band is attached to a rectangular link, this link being shaped to a knife-edge on the inner edge of its top side, the knife-edge resting on a grooved plate F embedded in upper arm A. The other end of the band it attached to an adjusting screw E in the usual way. A hanger is suspended from B on a knife-edge, and weights can be placed on this hanger as on any ordinary scales. The upper arm A is supported from some standard through a spring balance H (preferably of the dial type). A very simple and convenient standard can be made from $\frac{3}{4}$in. or 1in. pipe. The connecting link to the balance rests on a knife-edge in A. The knife-edges in A and B consist simply of ordinary machine bolts passing through eyes in the hanger and balance attachment, these bolts being filed to an edge on their bearing surface.

The motor is driven in such a direction as to lift up on the weight G, and the difference between the weight suspended at G and the weight registered on the spring balance is evidently the gross weight lifted by the motor. To this must be added the weight of the brake arm in calculating the brake horse-power. The effective weight of the arm is readily found by tying A and B together with a light cord or wire, and, with no weight at G (other than the hanger), noting the weight registered on the spring balance for each direction of rotation of the motor, the speed being the same in both directions. Half the sum of these two weights will be the weight of the brake arm, since, with one direction of rotation, the weight registered will be the weight of the arm plus the friction on the pulley, and with the other direction of rotation the weight registered will be equal to the weight of the arm minus this friction. As the load at G is increased and the attachment on the balance H comes down, the arms A and B may be kept horizontal by having an adjustment above the balance such that it can be raised or lowered, or the link connecting the balance to A may be made adjustable. A very sensitive balance H can be used, and may be protected from overstrain, in case the motor stops suddenly, by placing a support just below the weight G, such that the weight will drop upon it.

The brake horse-power is calculated in the usual way. The great advantage of this arrangement is that the motor may be run for any desired length of time on any one load without attention, since if the band tends to tighten on the pulley the lower arm B is lifted towards A, and the tension on the band is automatically released. The arms A and B should be suspended horizontally, and while it is impossible that they should both be exactly horizontal, the distance between them at the ends farthest from the pulley need not exceed $\frac{1}{2}$in., and the error, therefore, is negligible.

The above brake was brought out by Prof. L. W. Gill, of the School of Mining, Kingston, Ontario, and has been found so superior to the old Prony brake that the latter has been discarded altogether in the laboratories. The load can be adjusted readily, and will be maintained constant as long as desired.

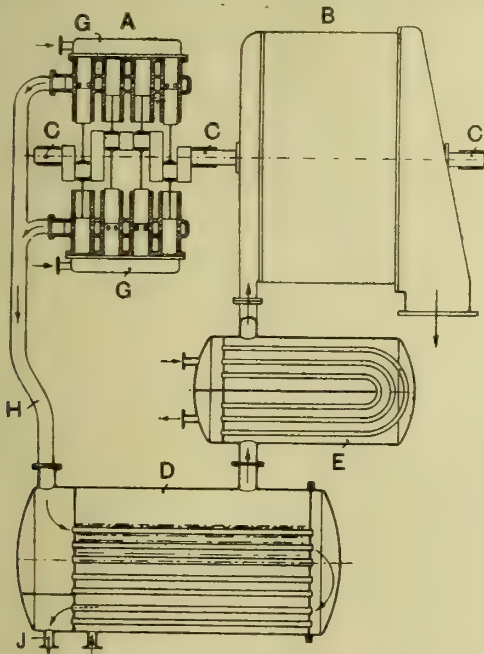
COMBINED RECIPROCATING ENGINES AND TURBINE PLANTS.

It is well known that combined reciprocating engines and turbine plants, in which the high-pressure element consists of a reciprocating engine and the low-pressure element of a turbine, are able with comparatively small dimensions of the working parts to utilise efficiently the high-pressure steam with an expansion ratio reaching to the extreme limit of possible expansion at the low-pressure end. Such an advantageous result cannot be obtained either with reciprocating engines alone or with turbines alone. One of the disadvantages in combined plants of the above type lies in the fact that the steam in the high-pressure element becomes more or less saturated with the lubricating oil, and when such steam passes to the low-pressure element, it becomes deposited on the turbine blades and reduces the efficiency of the turbine. The removal of the oil deposited from the turbine blades is a difficult and expensive operation. Further, in addition to being deposited on the turbine blades, oil is also deposited in the condenser, thereby diminishing the vacuum attainable, and effecting a further reduction in the efficiency of the plant. If, in order to remedy this defect, an oil separator is interposed between the reciprocating engine and the turbine, a complete separation of the oil from the steam cannot be effected, as the separator merely delays the formation of the deposit in the turbine and condenser, but cannot eradicate it.

A plant of the type above indicated in which, it is claimed, all access of oil to the interior of the turbine and condenser is prevented is shown diagrammatically in the accompanying illustration. This plant, the invention of Dr. Wilhelm Schmidt, 2, Rolandstrasse, Cassel-Wilhelmshöhe, Germany, comprises a steam generator arranged between the reciprocating engine and the turbine, so that the steam generator is heated by the exhaust from the reciprocating engine and supplies the steam for driving the turbine. With this arrangement it is claimed that not only is the interior of the turbine and the condenser kept perfectly free from oily deposits, but the interposed generator also acts as an accumulator which keeps the main steam generator protected against injury in the event of sudden variations of the load. This latter feature is of considerable importance in cases where steam of very high pressure is employed, as steam generators of this type have usually a very small water space and cannot respond easily to large variations of the load. In such circumstances the larger water space of the interposed steam generator exerts an equalising action, and allows the turbine, which is able to bear considerable overloading, to absorb the inequalities in the load. The drop in pressure of the steam during its conversion is small, while the loss of heat in the steam generator is also small, as the latent heat of the exhaust steam of the high-pressure element is almost wholly transmitted to the steam evaporated in the

generator. The deposition of oil on the heating surfaces of the intermediate steam generator does not cause any great injury, as the working pressure thereof is low and the generator may be constructed so as to be readily cleaned. An oil separator may be inserted between the high-pressure element and the steam generator in order to reduce the oily deposit on the heating surfaces thereof. In some cases a superheater may be arranged between the interposed steam generator and the turbine, which superheater will act very efficiently in view of the fact that the steam upon which it operates is free from admixture with oil. Such intermediate superheaters in combined plants as heretofore constructed are very quickly rendered useless owing to the deposition of oil on their heating surfaces. This disadvantage is obviated by means of the arrangement under notice. The advantages of the arrangement are particularly apparent in those circumstances in which steam of very high pressure is employed, as the losses caused on the conversion of the steam are then relatively smallest.

Referring to the illustration, a high-pressure element A and a low-pressure element B are provided. The high-pressure



Combined Reciprocating Engines and Turbine Plant.

element consists of eight single-acting high-pressure reciprocating engines situated in one plane, and acting upon a common shaft C. The low-pressure element B consists of a steam turbine acting also upon the shaft C. A steam generator D is arranged between the engine A and the turbine B, while a superheater E is interposed between the generator D and the turbine B. The engine A is supplied with superheated steam from a suitable generating plant, by way of the steam chests G. After performing work in the engines, the steam exhausts through the pipe H to the steam generator D, giving up its heat to the heating surfaces thereof, and becoming condensed into water which is drawn off through the pipe J. The steam generated in the generator D passes into the superheater E, preferably heated by high-pressure boiler steam, wherein it is dried or superheated, and thereafter led to the turbine to perform work therein. The exhaust from the turbine passes to a condenser. The water of condensation of this condenser is almost chemically pure, and may be used as feed-water for the generator D, thus preventing the deposition of scale therein, or the condensed water may be used for any other suitable purpose.

Electric Supply Undertakings.—A course of lectures on the management of public electric supply undertakings is to be started on October 14th by Mr. A. H. Seabrook at the East London College. The lectures will deal with the general aspects and responsibilities of management; the staff and employés; electric supply service; the head office; the general manager and the engineer; the secretary and the accountant; the station; mains, meters, and public lighting; the sales department; and tariffs.

MOULDING A WATER-JACKETED CYLINDER FOR A VERTICAL GAS ENGINE.*

By J. G. Robinson.

The title of this paper is somewhat misleading, as it is not the writer's intention to enter into a detailed account of the actual moulding operations involved in the moulding of a water-jacketed cylinder. Such an account would obviously be a waste of time at a meeting of foundrymen.

My purpose is to describe the methods adopted at our works to secure sound and clean castings, and by means of slides prepared from photographs of a mould in the different stages of its construction, it is hoped to make this quite clear.

The cylinder under consideration (Fig. 1) is one of four which go to make up a 350 b.h.p. gas engine. The diameter of the bore is 17in., the overall length 5ft. 1in.

By way of prefatory comment, I may point out that to the uninitiated and inexperienced certain difficulties in the

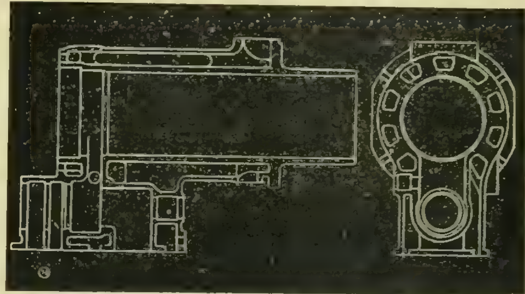


Fig. 1.

making of patterns and core boxes and in the making and casting of the mould may appear very formidable, whereas to the less critical these difficulties will be non-apparent. That there are serious obstacles to be overcome will be well known to one who has had experience of this class of work, but he knows equally well how to avoid the pitfalls ever awaiting the unwary.

As a result of exhaustive experiments, we have adopted the following method as productive of the best result. There will be noticed a variation in the thickness of the metal at the point where the flange is connected with the inner and outer walls of the cylinder, and also at the opposite end, where solid blocks are cast in to receive the studs for attaching the end cover. During machining operations these two points have been found to exhibit a spongy nature, and

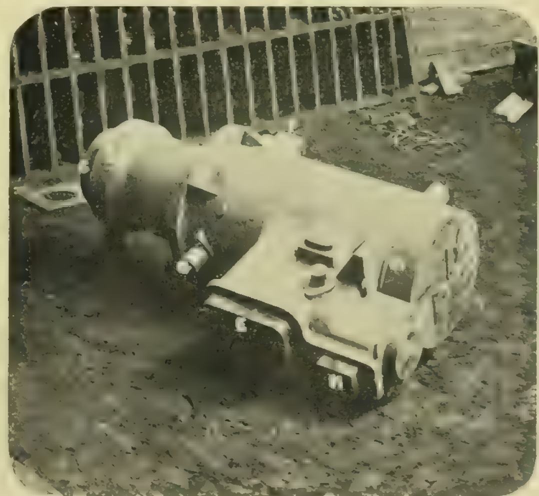


Fig. 2.

have proved the most prolific source of trouble, which has been overcome by the use of chills and a suitable mixture of metal.

The mould is made in dry sand. It is made on the flat and placed on end for casting. The valve-box end, being

* Paper read before the British Foundrymen's Association annual convention, Cardiff, August, 1912.

the part where the explosions take place when the engine is at work, must be perfectly sound; therefore, that end is cast down. To the other end, which is quite plain and easily extended, a rising head is attached to collect the dirt, &c. A full pattern is used for the outside, and the centre or body

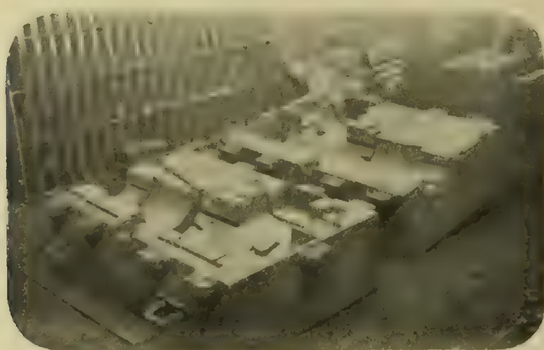


Fig. 3.

core is struck up on a barrel in loam. The jacket core is made in two half-boxes, which will be described later.

The pattern (Fig. 2) is jointed along the centre line. At the plain end a core print C of the same diameter as the body core is provided, whereas at the other end the core print D is of the same diameter as the jacket core, which is



Fig. 4.

carried through the end of the casting, and requires a bearing. To provide a bearing for the body core at this end, the internal diameter of the jacket core and the external diameter of the body core are made to correspond. The print E carries the part of the jacket core which extends round the



Fig. 5

valve box, the prints F and G being the other places at which the main jacket core has a bearing on the outside.

Prints H, J, K carry the valve-box cores, the remaining prints being merely for small local cores. The enlarged part L forms the rising head. A definite method of moulding, coring, and running having been decided upon, the actual moulding is now a very plain and simple matter, requiring no special skill beyond what should be possessed by a good moulder.

The method of running is as follows: The metal is dropped from the top, four runners 1¼in. and ½in., which are spaced equally round the body core, being used, Fig. 3. As this particular cylinder is rather long, a few cwts. of metal are run in at the bottom to form a cushion and prevent the metal cutting the jacket core where it drops. This is done by means of a down runner at the side, which must be provided for in the course of ramming up the bottom part of the mould, and can be seen in the illustra-



Fig. 6.

tion, which shows the finished mould ready for drying. A riser is taken from the flange and another from the head.

Before drying, part of the sand over the prints for the jacket core at the end, and the valve box in the top half, are cut away to facilitate stopping in round these cores when the mould is closed. The small cores are affixed while the mould is green, and are dried in position.

Fig. 4 shows the method of preparing core boxes. The small box in front is for the valve box. This core is made in halves in oil sand, strengthened by cast-iron grids, and is jointed when dry. For the main jacket boxes a flat bottom is prepared, and on it is placed a block of the form assumed by the thickness of the metal round the body core and valve box. The box ends are made to follow the thickness of the

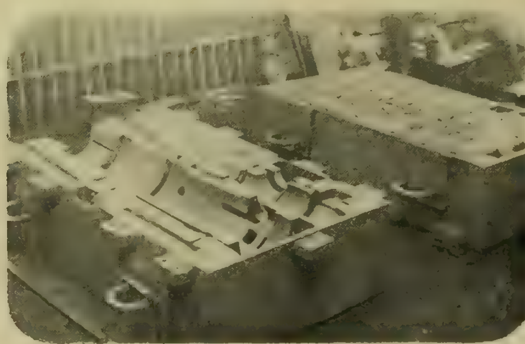


Fig. 7.

jacket core required, strickles being made the full length to work on these ends and strickle off the sand to the required shape. At the point where the valve box joins the body it is necessary to have pieces worked to the required shape, as shown, and used loose. These cores are made in oil-sand, and are strengthened by loose irons, which are easily removed when the casting is being fettled.

The vents in these cores are formed by placing wood wool bands in the centre of the thickness of sand during ramming (Fig 5). These all have a connection with the parts which have a bearing on the outer core prints. In the course of drying, these bands are more or less charred and form passages for the free escape of gas. After the cores are strickled off to the required thickness, the loose parts of the box are

removed and cast-iron plates fixed along each side to support the core whilst being dried. The space between the plates and the rounded part of the core is filled up with floor sand and struck off level. On the top of this is placed



Fig. 8.

the cast-iron plate on which the core is carried for drying, the whole being cramped together and turned over.

After being dried, any variation in the cores is dressed off by rubbing with a piece of emery stone, after which the whole is given a good coat of blacking. It might here be said that we find it necessary when using oil-sand cores to allow ⅛in. in 9in. for sinking. The connections with the vents can be seen in Fig. 6 on the finished cores.

The remaining core is that of the body. This is struck up in loam on a barrel in the ordinary way, except that provision is made for the chills before mentioned, which are placed opposite the two thick parts of metal in order to produce an equal rate of cooling and prevent spongy or drawn places. These chills are made 6in. wide and 1¼in. thick in six segments, each of which is ⅝in. short of a sixth of the diameter required. The spaces between them are filled with loam, and allow for the contraction of the casting, so that the chills are easily removed when the casting is being fettled. The core is made of such a length that it extends about a foot beyond the end of the moulding box, in order to project well above the runner box when casting.

In assembling (Fig. 7), the first core to be fixed is the bottom half of the main jacket core. This rests on the prints D, E, F, G, but in addition to these, two double studs are placed under the end nearest the flange, as the two side cores are not sufficiently strong to support the weight. When this is fixed (Fig. 8), there is a bearing at each end for the body core, which is next placed in position. This core is inside the moulding box at the bottom, packings being placed between the barrel and the box end to support the weight when the mould is placed on end. The space at this end of the core is rammed up with sand, a hole being left through the bottom of the box to take the vent from that end of the



Fig. 9.

jacket core. At the other end a tube is connected with the vent and carried through the side of the box.

The valve-box core is now fixed and the other half of the main jacket core lowered into position, Fig. 9. Pieces of clay to try the space left for metal are placed on the cores, and the top part of the mould lowered on. When all thicknesses have been ascertained, studs similar to those mentioned in connection with the bottom part are placed on the jacket core and the mould is closed. The open spaces over the prints before mentioned are rammed up with sand, the vents being taken off in the same manner as in the bottom part and the whole securely bolted together.

The mould is then turned up on end and lowered into a pit for casting, Fig. 10, A large runner box is now fixed, and a separate box for the riser from the flange. Plugs are placed over the runners and riser round the body core, and a piece of tin over the down runner on the side. When casting com-



Fig. 10.

mences this tin allows a certain amount of metal to be poured into the runner box before it is melted, and thus prevents any dirt getting down the runner. After a few cwts. have been allowed to run into the bottom and the runner box has been well filled, the plugs over the other runners are drawn off. When the mould is filled the riser plug is removed and the ladle taken to the riser from the flange, metal being poured in there to feed the thick part.



Fig. 11.

As soon as the metal is set the core barrel is withdrawn in order to assist the cooling of the inner walls of the cylinder, which are of a thicker section than the outside. The box is then turned down on the flat, and the bolts through the lugs eased to allow for the expansion of the box, as otherwise there is a danger of the lugs being broken off.

The final illustration shows the finished casting ready for the machine shop.

Mines Rescue Station for Rotherham.— Arrangements have been made for establishing a rescue station in connection with mining in the Rotherham district. A site for the necessary buildings has been selected. It is understood that the equipment will be of the very latest. The station will be managed by a local committee representing the various collieries.

THE JOINING OF METALS.*

BY ALEX. E. TUCKER, F.I.C.

The expression "The Joining of Metals" clearly includes such processes as riveting, folding, sewing, and dowelling. As these, however, are essentially mechanical processes I do not propose to discuss them. On the other hand, I shall be able to show that many industrial operations, such as riveting and folding, are now being replaced by autogenous welding and other recently introduced means. Methods of joining metals by physical processes, such as welding and brazing, give rise to some interesting considerations, and it is the physical process involved in such operations and the commercial application of such operations which I propose to discuss.

The phenomena of cohesion and adhesion, on which the joining of similar or dissimilar metals depends, are frequently referred to as one and the same thing. It is therefore well to decide whether or not this interpretation is justified, and if it is not justified, to distinguish between them. It is true that in brazing copper and soldering together two pieces of brass other actions, such as alloying, come into play; but there are many cases on which I shall enlarge where cohesion or adhesion, or both, are depended on alone for the result, and lead to important industrial applications. The etymology of the two words assists to some extent, but etymology is sometimes misleading, because current use and the authority of text-books frequently diminish its value. Perhaps I may illustrate the difference in the two phenomena of cohesion and adhesion as follows:—

A sheet of paper may by well-known methods be divided into two sheets, the cohesion of the paper being thereby overcome; but unless the adhesion of the sheet of the material to the two surfaces of the material employed in the experiment is greater than the cohesion of the sheet itself, it cannot, of course, be so divided. Cohesion is therefore the tenacity of a material, and is functional and molecular. It is the tensile strength—in this case the transverse tensile strength—of the body. Adhesion is the external and adventitious property of media and conditions which resist the separations of the materials, and it may be less or greater than the cohesion or tensile strength of the bodies involved. In other words, the force which acts between adjacent parts of the same substance is called cohesion, while the force which acts between portions of different kinds of matter is called adhesion. Both forces are quite inoperative between two portions of matter separated by any distance which we can directly measure. Quincke examined the conditions of their operation, and found that the greatest distance at which the effect of these forces is sensible for various substances is about the twenty-thousandth part of a millimetre.

During unknown periods advantage has been taken of the phenomena of cohesion and adhesion in inlaying and buhl work, in which the strength of the joined work exceeds that of the material joined. Thus a design is drawn on two surfaces of wood—these designs need not be identical—and the design is then worked in with a thin glue, the other parts being damped and dusted with French chalk, to retard adhesion. After submitting the two pieces of wood—with an intervening layer of coloured wood—to pressure, and allowing the whole to dry, the intervening layer may be split into two lamina, after which the designs are brought out by cutting away the superfluous wood, followed by sandpapering and polishing. I allude to this illustration of joining of wood and other materials because, for reasons which I shall give, there is an application of the property of adhesion for the production of art metal work, though I do not know that it has ever been done commercially. I have only seen the results of experiments in this direction. In this case, however, the layer of metal is not split into lamina.

A more immediate example of cohesion may be given. In close annealing iron and steel sheets it sometimes happens that two or more of the clean sheets, especially those at the bottom of the box, will stick together so completely that, instead of separating, a sheet will, if sufficient force be applied, part into lamina before the adhering media will be broken down. The same thing happens in rolling many kinds of metal sheets when they are free from oxide—indeed, if oxide were present on the surfaces the action could not take place; on examining the points of contact it will be found that intercrystallisation has taken place, and true welding has therefore occurred. Allied examples of this effect often occur in the seizing of shafts in their journals through failure of lubrication, or where a steel shaft has been allowed to revolve in or against a steel bearing or mass of similar quality. An interesting case is recorded in which the two ends of a broken shaft accidentally welded up again by the heat developed at the surfaces.

Generally, if surfaces of the same material are sufficiently parallel and polished, great adhesion may be obtained by simply laying them together. Plate-glass sometimes shows this effect so completely that the two may be cut and worked as a single piece. If the materials having such surfaces are ductile, and pressure is applied either by rolling or by simply dead weight, the effect is accentuated. I should regard such results as illustrations of cohesion rather than adhesion. These results have great practical value, to which I shall presently allude; but they seem to be only an extension of the undoubted cohesion effect, shown when two pieces of lead or phosphorus, or metallic powders, or mixtures of powders, are compressed. Under the condition of pressure the effects are greatly accentuated by time and temperature, and true welding appears to occur.

The expression "welding" (A.S. weallan, to boil), in connection with non-ferrous metals, is borrowed from practice in iron and steel working, in which the pieces to be joined are brought to a high heat, often fusion heat, and are then hammered together. This operation is one which, from a physical point of view, illustrates the difficulty of saying whether the result is due to cohesion or adhesion. When high heats are used cohesion would appear to act, but it is well known that fusion is not required for effecting a union of several metals to bring about a joint having a great degree of strength. Two clean pieces of any soft metal, such as lead, may be hammered or pressed together and a fairly strong joint made. Analysts often readily repair a perforated platinum crucible by cleaning the metal round the hole and hammering a piece of bright platinum while the two are at a red heat. The well-known Coffin's weld is another instance; here the pieces of iron or mild steel are heated greatly below the fusion temperature in an ordinary reducing atmosphere and pressed together. The join shows remarkable strength, and Dr. Stead had recently shown that if the operation is modified, so that time is given to the period of contact, the crystals of the two surfaces interlock and the requirements of a true weld are obtained, the strength of the weld as a whole being determined by the degree of contact of the two original surfaces. Hence, by extending the time or raising the temperature, and maintaining a non-oxidising atmosphere on the surface, an entirely satisfactory weld may be obtained at a temperature much below that ordinarily employed. These results illustrate in a practical way the conclusions arrived at by Quincke, to which I have already alluded.

Although there is a clear difference between the phenomena of cohesion and adhesion, and the difference is important when discussing the phenomena of joining of metals, it must be admitted that under certain conditions it is difficult to distinguish beween the influence of the one and the action of the other; thus if two pieces of brass be joined by ordinary tinman's solder, it can be shown that a true alloying is obtained between the solder and the two surfaces. The strength at the surface of the pieces of brass will be the strength or adhesion of the alloy, but the strength of the work as a whole will be the strength of the intervening layer of solder. On the other hand, if instead of tinman's solder a material be used such as india-rubber, cement, or glue, or a film of oil or even water, the join will be effected by adhesion, as no molecular combination obtains between the brass and such media.

Although in the latter case the force required to separate the pieces of brass may be considerable, it appears to be limited to the surface tension of the intervening layer. This is the explanation of the well-known fact that in cementing two surfaces by an intervening layer, provided the surfaces can be "wetted" by the material forming the layer, the thinner the layer used the stronger will be the adhesion. The join will also be more permanent, because it more completely adapts itself to the changes of temperature to which the

* Paper read before the Institute of Metals, September, 1912.

whole may be exposed, whereas if a thick mass were used it might expand unequally with it, and possibly destroy the cohesion.

Methods Used Practically for Joining Metals.—The methods in practical use for joining metals may be divided in the order of their importance as follows: (1) By metallic cements, such as tinman's or brazing solder, which have to be brought to the plastic or liquid state, and whose constituents should be capable of alloying perfectly with the metals to be joined. (2) By autogenous fusing, in which the two parts are heated and liquid metal of the same character run round the mass, or the parts are heated to fusing point, and the surfaces worked together by pressure or hammering. (3) By the use of a cementing metal under pressure, generally that of a rolling-mill, and at ordinary or only slightly raised temperatures.

In respect to the first method, it is obvious that the fusion point of the solder must be lower than that of the articles to be joined, and as, speaking generally, the higher the melting point the stronger the solder, it follows that it is desirable that such solder or brazing spelter should be used whenever possible, the melting point of which is only a few degrees less than that of the metals to be joined. The solder should also have, if possible, the same characteristics, such as malleability, colour, and hardness. This is especially important in jewellery work, and also in the brazing of copper. Such conditions imply greater skill on the part of the operator, but the union will be the more perfect, and the process under such conditions more nearly approaches autogenous soldering.

In the jewellery trade it is usual for the workman to make his own solder, because the colour and standard of purity with respect to the contents of gold or silver, have to be very finely adjusted to the work in hand. The result is that, without any colouring of the finished work, it is often impossible to detect the join. It is hardly necessary to say that such results are only obtained by great experience. In joining such metals as britannia metal and pewter, both of which are alloys containing much lead, very fusible solders must be used: these generally contain bismuth, and the flux used is tallow or olive oil or its equivalent; further, instead of the flame of a blowpipe or a soldering iron being used, the workman will effect the join by directing a stream of hot air on to the parts, in this way greater control of heat being obtained.

Tinman's Solder.—In the use of this care should be especially taken to avoid the presence of zinc, and in certain cases even a trace of zinc is especially prejudicial; it thickens the solder, and probably on account of its liability to oxidation, forms a superficial scum which the ordinary spirits of salt is incapable of dissolving. If the presence of zinc be suspected, the addition of a few drops of acid will help greatly. Antimony is frequently present in tinman's solder—this, by forming a cement of higher tensile strength, may, under special conditions, make a joint of greater strength. In the use of solder, either soft solder or brazing solder, it is clearly the correct method to raise the work to the highest temperature that the solder and the work will stand, because under such conditions the penetration of the solder into the surfaces to be joined will be better, and further, the soldering medium may then be squeezed out to the maximum from between the surfaces by suitable means, and hence the requirement can be met, that the thinner the layer of cementing material and the closer the surfaces are together the stronger the join. Additional strength, because of the additional intimacy effected, may be given to the work by rubbing the surfaces carrying the liquid solder together; in the same way it is always well to rub the soldering iron, when possible, over the work when it is used, the "wetting" of the surfaces is then more perfect, and no stripping of the solder is possible when this rubbing is done. In order to obtain a lower melting point in tin solder, bismuth, and sometimes cadmium, is added. Such solders are used for delicate work, as is occasionally required for electrical fittings. I am aware of bicycles having been built in which the tubing was fixed in the respective lugs with soft solder instead of the ordinary brazing. They stood every test, and, personally, if the lugs are carefully machined to only a fraction larger than the tubes, I should prefer this method of frame-building.

The conditions here are very different from those in the case of the brazing of brass and copper, because it happens that all the metals employed in brazing and tinman's solders destroy the character of the steel they are intended to join if they are heated sufficiently with the steel, while they have no corresponding injurious effect when used for brass or copper work. When soft solder is used the thin gauge tubing is not so likely to be spoiled by deteriorating action on the steel, or by being oxidised at the heat necessary for brazing; and, further, on account of the greater liquidity of the soft solder, it will, when properly applied, sink into the small annular space between the lugs, &c., and the tubes more completely than can be expected with the more viscous flux and brazing solder. The reasons that soft solder is not used for such work are, firstly, because the heat of the enamelling stoves makes its use risky; and secondly, popular prejudice—a soft soldered frame sounding badly to the untechnical layman

It is a common habit of workmen, and amateurs who have soft soldering to do, to depend on the ordinary bit, when they might use a bunsen or blowpipe. These, in many cases, would heat the work more generally than is possible with the bit, and would allow of the penetration of the solder into the surfaces, and the subsequent squeezing out of the excess of solder. On the other hand, many forms of soldering bits are now in use, in which a bunsen burner connected with a light flexible tube is employed to heat the bit, and the flame can be conveniently made to heat the work as well. This form of soldering iron has many advantages. One of the best fluxes I have found for ordinary soldering can be easily made by macerating flux skimmings from galvanising pots with weak hydrochloric acid. On filtering, the solution is ready for use, and is an ideal flux, because of the chloride of ammonia present with the chloride of zinc. No iron or lead is dissolved if the acid added is not in excess. Solder is often used in the form of granules or strips of various sizes, and in this form is very convenient for routine work. In the case of spectacle frames or other light articles a large amount of work can be prepared, on each of which a small piece of solder, either in the form of a granule or a strip, is placed with flux on the part to be joined. The articles are then put in a tray, which is afterwards taken to a muffle working at a convenient heat, or in some cases it is sufficient to put the work on a metal plate, heated by a gas flame or even a spirit-lamp. Brass tubes are often made by bending the strip through dies, and fixing a wire of suitable composition in the overlap with borax, or the borax may be mixed with finely granulated spelter. On passing the work through a furnace to raise it to a red heat, the spelter runs perfectly and a good join is made. The flux is then dissolved off the work, and the tubes are finished by drawing through dies with or without a mandrel.

The best brazing, if it may be properly so termed, is done with "silver solder," thus the blading used in turbines is all fixed with silver solder. It is, of course, of the utmost importance that the small pieces used in the construction of turbine motors shall be immovably fixed and cemented in position, on account of the heat and centrifugal strain to which they are subjected. Various silver alloys are used, but they are generally about 60 of silver, 23 of copper, and 17 of zinc, the flux used being borax, or borax and carbonate of soda. Such a mixture is remarkably liquid when in the molten state, and on this account penetrates interstices which ordinary brazing spelter would fail to fill.

Brazing Solder.—The composition of ordinary brazing solder ranges within wide limits; the analyses of samples I have examined show a variation from 61 to 33 of copper, and 39 to 67 of zinc. The tin may vary from nil to 14 per cent., and the lead from nil to as much as 3 per cent. Any of such metals may be and are used for brazing, in accordance with the character and requirements of the work to be done. The higher the percentage of copper the higher the melting point, and the higher the percentage of tin the lighter the colour. We thus have a very large series of alloys available for very varied requirements. The presence of other metals when in small amounts is often of no consequence in the brazing of brass or copper, though obviously in all cases it is very desirable in important work, such as the brazing of high-pressure steam pipes or where great strength is required, that the composition of the brazing metal shall approach as closely as possible to that of the metal to be joined, as only under such conditions can the maximum strength of the joint be obtained, and it is the non-observance of these conditions which has led to disaster. The skill of the workman is often

limited to the fluxing of the solder, and seldom extends to an appreciation of its composition.

When, however, we come to brazing iron and steel, the importance of purity is very much greater, and I have found the presence of tin in brazing solder intended for bicycle frames to be very injurious. The explanation is probably to be found in the extraordinary deleterious effect of tin on iron and steel. It is well known that a very small amount of tin scrap, if allowed to get into a bath of molten steel, will make it very red short, and when brazing solder containing as little as 0·5 per cent. of tin is used for brazing bicycle frames, I have found that the joints are very unsatisfactory and unsafe.

An ingenious method of making a brazed joint is by connecting the two parts to be joined with the terminals of a suitable dynamo. On account of the local resistance the two parts become heated, and if suitable brass wire is wrapped round the tube, in the case of a cycle frame, and the whole surrounded with a reducing gas, such as hydrogen or coal gas, a very perfect joint is obtained without any borax or other fluxing medium. The reducing gas under such conditions will ensure the absence of any oxide of iron or other metal used, and no previous cleaning is required. Such method of joining has the great advantage that there is no borax to remove from the joint. On account of its great hardness this removal of borax is a serious matter, and much money has been spent on experiments to remove it by pickling and other methods. It is best removed by sand-blasting, the whole frame being so treated leaving an excellent surface, on account of its roughness, for enamelling.

Liquid Brazing.—Several patents have been taken out for details of apparatus in which a bath of brazing spelter has been kept liquid. The parts to be joined are dipped in the molten metal, the metal being prevented from adhering to the parts that have not to be brazed by applying a coating of blacking to them. The advantage of this method consists in the fact that less metal is used in making the joint, as so little is lost in applying it, and also the heat is general on the joint instead of being local, and I have no doubt that on routine work the consumption of gas for heating is less than when blowpipes are used, and, of course, blast is not required.

A modification of brazing is the use of copper in the form of sheet or wire. Under the Simpson patents tools are thus made in which the cutting part is a small piece of high-speed or other steel, while the shank is mild steel or iron. In making, say, a lathe tool by this process, a bar of square mild steel is taken, and a channel planed or milled out on it in which a suitable square piece of high-speed steel fits. The two or three sides being clean, strips of copper are fitted in with a special flux, and the whole highly heated to the fusing point of the copper. After welding, the compound tool is cleaned up and treated for hardening and tempering in the ordinary way. There are some features about this process of building up tools which seem to have considerable merit. First, if ordinary brazing were used, the hardening of many tools implies such a temperature as would often destroy an ordinary brazed point. The zinc would possibly be volatilised, which is not the case when copper alone is used, the temperature of fusion of the copper being so much higher. Secondly, it is conceivable that the weld would be considerably stronger than with an alloy of zinc, because while copper alloys to a considerable extent with iron, the same cannot be said of zinc, which therefore under such circumstances would become a deteriorating element. Thirdly, the saving of expensive material, such as alloy steel, must be considerable in the case of heavy machine tools, as only a small portion of metal is ever in actual use. In a sense, therefore, the shank becomes a tool-holder, without the disadvantages of the latter in respect to unsteadiness, difficulty of setting, &c. The process lends itself to many interesting applications; thus milling cutters may be made having a core of mild steel instead of tool steel. Hardening and tempering such cutters is a source of much difficulty and loss through distortion and cracking, and if the compound cutters can be so produced the possible economy should be considerable. There is no doubt as to the perfection of the join, as I have seen pieces of steel joined by the process which on splitting did not part at the weld, the original metal appearing to be the weaker material.

The Brazing of Cast Iron.—A process has been invented by F. Pich (Berlin) for the hard brazing of cast iron in a smith's hearth. The patent consists in the decarburisation during brazing of the cast-iron surfaces to be united, and in bringing at the same time the molten brass solder into close contact with the cast-iron surfaces which are decarburised, but without exposure to the air. For the decarburisation of the surfaces copper oxide is used, which is mixed with borax, as a flux, until it has the consistency of a paste. This is applied to the surfaces to be joined, which must first be carefully cleaned. The cast-iron pieces are then firmly tied together with wire and heated. The borax first melts, protecting the surfaces from oxidation, and taking up any oxide that may be still clinging to them. It also precludes the attacking of the copper oxide by the oxygen of the air. As the heating proceeds the copper oxide fuses and gives up to the now red-hot surfaces its oxygen, which combines with the graphite of the cast iron, forming carbon monoxide and dioxide, while the metallic copper is set free in a very finely divided state. This alloys with the brass solder as it melts when strewn on, and the new alloy combines with the decarburised iron of the surfaces which it is desired to join. Specimens of cast iron united by this method were prepared and subjected to tensile and breaking tests, and the summary of all the results shows that when the brazing of cast-iron pieces is carefully performed according to the details given by Pich, the strength of the pieces so joined is virtually equal to that of the solid material.

The Soldering of Aluminium.—As is well known, numerous patents have been taken out and numerous mysterious mixtures have been advertised for the so-called soldering of aluminium. In nearly every case the result is that, while fairly satisfactory for a short time, the join failed after a time, varying from a few days to some months. One of the most severe tests to which such joins in aluminium can be subjected is that of warm steam. Joins which look well and are apparently mechanically strong, fail rapidly when submitted to this test. In all soldering, it is obvious that the flux used must efficiently clean the surfaces of the metals to be joined, otherwise no alloying of the solder used with the surfaces is possible. In the case of aluminium very few materials adapted for such fluxes are available, the requirement being that they shall absorb oxide of aluminium. Another detail of importance is the great heat conducting of the metal. A consideration of the results obtained with all the so-called solders of aluminium shows that the metal is so susceptible to electrical action and oxidation that the use of any metal in which aluminium itself does not preponderate is hopeless. The best results have invariably been obtained when the solder was of the same composition as the material to be joined. This condition involves the principle of autogenous soldering, which will be subsequently dealt with. The best flux used is a mixture of alkaline aluminium chloride, with the addition of fluorides, such as potassium fluoride or calcium fluoride. When these are mixed in suitable proportions and damped with alcohol, and heated on a strip of aluminium, the surface of the metal is cleaned perfectly. It therefore follows that if two surfaces of aluminium are so cleaned, and an alloy containing a high percentage of aluminium, with such addition of other melted metal as will reduce its melting point slightly below that of pure aluminium, applied with the flux named, that a very satisfactory join will be obtained. The heat such as from a spirit-lamp or bunsen burner must, however, be applied from below the work. I have seen such joins made over a spirit-lamp which stood every test, including that of the steam test.

Difficulties arise from the presence of high percentages of aluminium in alloys in connection with soft soldering. These may be largely overcome by coating them electrically with copper. The following directions for soft soldering their alloys, containing from 5 to 10 per cent. of aluminium, have been issued by an electric smelting company: "Cleanse well from dirt and grease. Then place the part to be soldered in a strong solution of sulphate of copper, and place in the bath a rod of soft iron, touching the parts to be joined. After a while a copper-like surface will be seen on the metal; remove from the bath, rinse quite clean, and brighten the surfaces. The surfaces can then be tinned in the ordinary way." It is obvious that these directions are intended to be used only where an ordinary electrotyping plant is not available.

(To be continued.)

THE COMMERCIAL ECONOMY OF TURBINE PUMPS.*

BY F. ZUR NEDDEN AND H. B. MAXWELL.

(*Concluded from page 389.*)

The existing systems of balancing the axial thrust of turbine pumps may be divided into two classes, viz., those in which the balancing effect is affected by wear, and those the action of which is independent of wear. The first group require the addition of a thrust bearing strong enough to take up the maximum possible axial thrust of the particular pump. These systems have the advantage of cheapness, and as the axial forces coming into action are small in small pumps there is no real objection against their adoption for the smaller sizes, the more so as no heavy economical losses are incurred by a decrease of efficiency in pumps which are only using a small maximum horse-power. The system most generally known to be dependent in its action on good running fits, and therefore failing if bushes wear out, is shown in Fig. 22. The holes in the back of the impeller are intended to equalise the pressure prevailing in the inlet area of the impeller with that in the opposite chamber on the back, which otherwise would be identical with that existing at the circumference of the impeller. As soon as the bushes wear, great quantities of water flow out of the chamber into that in front of the holes, and by being stored up there tend to press the rotor towards the suction side. The leakage water firstly represents a loss and secondly often partially breaks the vacuum formed at the inlet of the first stage, thereby causing more or less serious suction difficulties.

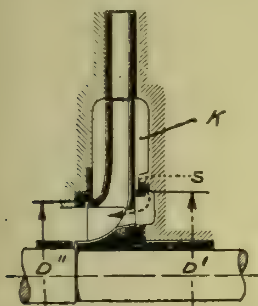


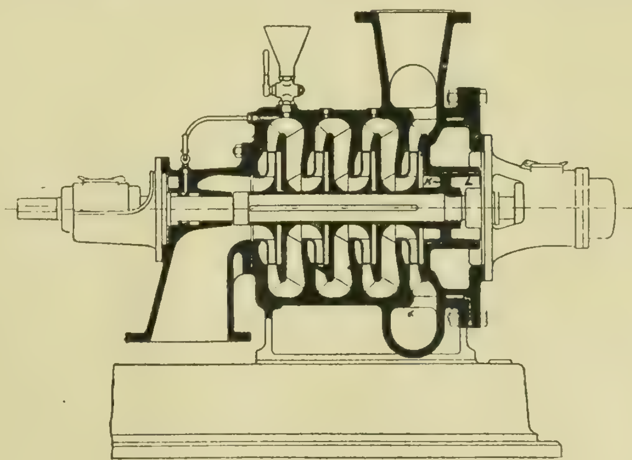
Fig. 22.—Balancing Device for One-sided Impeller.

The advantage of balancing the different chambers with one balancing piston at the end, as per Fig. 23, mainly consists in avoiding these suction troubles, but the balancing piston in itself causes an extra loss by acting as an additional water brake by its large surfaces revolving in water with great velocity, and the clearance between the piston and the casing will, firstly, wear out sooner, and, secondly, its wear will cause greater leakage losses, as the pressure difference between chambers K and L is not that of one single stage, but is the total pressure generated by the pump.

The only two systems known to be absolutely independent of wear and tear are the self-adjusting disc and the counterposition of impellers. We shall presently see that they also enable the designer greatly to reduce the possibilities of leakage. The self-adjusting disc is known from various steam turbine designs, and was first, and is still, very successfully applied to turbine pumps by Messrs. Sulzer Brothers. Fig. 24 shows a pump of this design as patented by Messrs. Schwartzkopff, and also applied, for some of their bigger pumps, by Messrs. Jens Orten-Boeving and Willans and Robinson. The essential feature is that the clearance s^1 which forms the connection between chambers a and b is an axial, not a radial clearance, and therefore depends on the position of and the forces exerted by the rotor. The pressure difference between chambers a and b counteracts the axial thrust in the pump which is directed to the right-hand side when looking at the picture. The clearance s^1 is, therefore, automatically kept just wide enough to store up the water contained in chamber a, so that its pressure keeps the rotor in exact equilibrium. Should the faces which form the clearance s^1 wear off, the clearance itself will nevertheless always readjust itself so that the above condition is maintained. The water loss caused by this balancing disc will, therefore, remain pretty constant throughout the life of the pump, and it will, moreover, always be a minimum. The leakage between the stages is reduced to the leakage round the shaft at G, Fig. 25, *i.e.*, through a clearance of minimum diameter, and to the clearance C on the outer circumference of the inlet of each impeller, while the losses through a clearance at the back of the impeller and its holes, as per Fig. 22, are here avoided. The pressure difference driving the water through the clearance G, Fig. 25, is only that generated by the guide apparatus, whilst an arrangement, as per Fig. 22, subjects both ends of the clearance round the boss to the pressure difference of one full stage, and therefore must cause greater loss.

The second balancing system independent of wear in its action is that of the counterposition of impellers, the principle of which is shown in Fig. 26, and generally called the "old Sulzer system," being now applied by this celebrated firm only to sinking pumps. It was abandoned in horizontal pumps principally for reasons of high manufacturing costs and weights, but not because it had ever failed. As a matter of fact the balancing action of a strictly symmetrical design is not only the most natural form of balancing, but also works out to be the most reliable and economic system in practice. By counterposing, not the single impellers, but two groups of impellers, as per Fig. 27, Messrs. Weise & Monski succeeded in obtaining a type considerably less complicated than the former and having the additional advantage of subjecting the pressure stuffing-box to only half the total pressure generated by the pump. There is no balancing disc with its unavoidable clearance, and therefore no loss through it. The leakage round the circumferences of the inlets of the impellers is reduced to a minimum by the introduction of a labyrinth consisting of axial clearances as well as radial ones, and forcing any water which leaks through to flow towards the centre, the centrifugal force counteracting and reducing leakage even when the labyrinth becomes worn out. The only disadvantage of this system appears to be that its application is restricted to an even number of stages. This, however, is only a theoretical disadvantage, for it is obviously possible either to take up the thrust of the one and only odd stage by means of a thrust bearing, or, as is actually done by Messrs. Weise & Monski with never-failing success, to balance the odd stage in itself by any of the methods adopted by other makers to balance the whole pump. It will be seen particularly that the machined face at the back of the third impeller can be made to act as a self-adjusting disc. The dimensions of this disc, and therefore the loss of water caused by its action, can be reduced considerably as compared with the ordinary balancing disc, as, in the worst case, only the thrust of one odd impeller has to be balanced, whilst the balancing force is exerted by a differential water pressure two or three times as great as the pressure generated by one stage.

Though, therefore, the manufacturer can doubtless do much to protect the customer against undue wear and tear, the users of turbine pumps can themselves contribute at least as large a share towards this end. To ensure the selection of the most suitable material the customer can do much by supplying makers with water samples or analyses. Every conscientious maker of turbine pumps will use the best materials modern metallurgy is able to supply him with, and the expense incurred for high-grade material is always warranted, as it is almost incredible how much quicker bad or even indifferent material is worn out than a special "ship's impeller" bronze, tough cast iron, &c. But even the best material is powerless to combat chemical effects, and a bronze lining, if in perfect contact with cast iron, often sets up electrolysis and hurries on destruction instead of preventing it.


Fig. 23.

The principal means, however, by which the user can

* Paper read before the South African Institution of Engineers.

reduce the repair bill and increase reliability is a large and well-laid out sump. It is remarkable how seldom one finds a good sump in England as compared with the Continent, and, of course, there are reasons both for and against large sumps. Doubtless continental, especially German miners often overdo the thing in blasting out a sump, the costs of which are many times greater than the sum spent for the pumps which are to benefit by it. But it is often possible, by a little timely deliberation when planning the drainage level of a mine, to arrange the pump station so that old cross-cuts can be used as sumps, and the authors have often found it possible to make use of the fact that a smaller height is required for turbine pump stations than for piston pump chambers, by partitioning

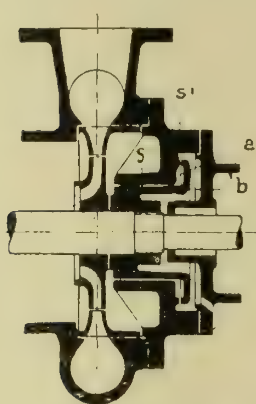


Fig. 24.—Combined Piston and Disc Balancing Device.

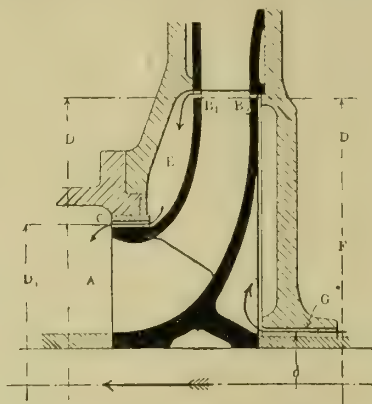


Fig. 25.—Location of Leakage Losses.

existing pump stations horizontally into two parts, using the lower one as a sump for the new turbine pumps, which can then suck in the most desirable manner from directly below them. Whilst it is, therefore, often possible to obtain large sumps without any considerable expense the benefit derived from them is almost incalculable.

(1) By allowing all the impurities contained in the water to thoroughly settle (for which purpose cross walls and hurdles in the sump are of great value) the wear will be reduced to a minimum, the repair bill kept low, the life of the pump lengthened, &c. An old miner once expressed his view that "the proper way to lift water is by a pump, and the proper means to lift solid matter is by a shovel and skip, and a good sump is the means of separating the solid from the liquid in order to then lift each by the proper means." This same man used an arrangement in his sump, consisting of a large basket filled with coke, which fitted tightly into the cross-section of the sump. By means of the lifting tackle in the pump station this basket was exchanged every few days for an interchangeable one, and it was really incredible what an enormous amount of solid matter was found in the basket and how clean the water pumped to the surface was. It is possible that by using limestone instead of coke, an additional purifying effect as regards admixtures of acids might be obtained, and that such arrangement might prove useful for ore mines in this form.

(2) By accumulating the influx of at least 16 hours it becomes possible: (*a*) to pump during one shift only and save the salary of at least two attendants; (*b*) to install a bigger pump having a more favourable relation between duty and head, and, therefore, running at a better efficiency; (*c*) to avoid throttling the pump so that even with 3-phase current the commercial efficiency is a maximum; (*d*) to lengthen the intervals during which no repairs have to be made as the pump is only running one-third of the whole time; the incalculable factors generally combined with standstills for repairs are, therefore, lessened and the real economy will more nearly coincide with the original calculation; (*e*) to obtain a higher reliability of the plant as the sump prevents the mine from being flooded for a much longer time; (*f*) to improve the load factor of the power plant by pumping during the shift showing the minimum loads. The authors, therefore, would take this opportunity of strongly advocating a more universal introduction of large sumps in connection with turbine mine drainage plants.

Questions of wear are surely in no case so decisive for the success and economy of turbine pumps as with vertical high lift sinking pumps. Here, as a matter of fact, the importance of the guaranteed efficiency nearly completely vanishes as compared with the costs incurred by only a short accidental stoppage, and the economy of a turbine sinking pump mainly, if not exclusively, consists in its reliability, its capability of withstanding the attacks of the worst possible water, and in its handiness in operation. It must further be borne in mind that in many instances the small space occupied by vertical turbine sinking pumps and their small weight, in proportion to their capacity, make it possible to sink shafts in the ordinary way, where, without them, it would be necessary to resort to artificial and expensive processes such as freezing or similar means—if sinking operations were not abandoned altogether.

Of course, there is the undeniable fact that the head of a centrifugal pump is inseparably connected with the speed. Now the squirrel-cage alternating-current motor, being the simplest and safest motor to resist the influences of moisture, is, and will probably remain, the most suitable motor for a sinking pump. The speed of these motors is practically constant for all loads, while, on the other hand, the head and duty of the sinking pump must necessarily vary with the inflow of water and the increasing depth of the shaft. In the case of multi-stage pumps the difficulty can be overcome to some extent by means of dummy pieces which are replaced by proper impellers as the depth of the shaft increases. This method is, however, a somewhat poor compromise in so far as a gradual increase of the head is met by a few, but large, steps; moreover, the exchange of the dummy pieces for impellers involves a considerable amount of work and loss of time, for to do this properly the pump must be raised to the surface and partially dismantled.

A better solution of the problem has recently been adopted in several instances by providing separate generator sets for each sinking unit. In this way it is possible to run the pump at any speed which may be desired, and to suit it to the corresponding head. The economy resulting from this method is obvious. With this arrangement it is further possible to avoid another serious disadvantage in the application of squirrel-cage alternating-current motors for driving these pumps, viz., the shocks arising from the starting up of such motors against the brake torque, *i.e.*, 30 to 50 per cent. of the full load torque, as the whole unit can be smoothly started up along with the generator. This method has also the further advantage that it permits of making up, by increasing the speed of the generator, for any deficiency in volume and head which inevitably occurs in every sinking pump. Especially whilst draining the shaft after blasting this method of temporarily speeding up, and thus pumping "full bore" until the bottom is dry again, is of great convenience in rapidly restarting the sinkers' work.

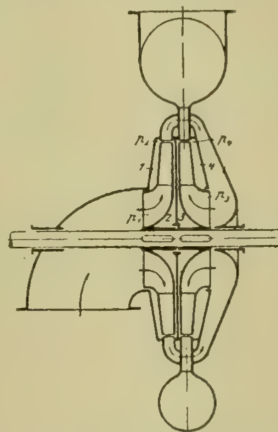


Fig. 26. Schematic Diagram of Device for Balancing by Counterposition of Impellers.

Great progress has been made in improving the balancing arrangements of the rotor, and the cooling of the bearings both for the vertical pump and motor, and the developments of metallurgy year by year permit more powerful resistance against the influences of grit and sand. Probably the most important step towards perfection has been made by introducing means to overcome one of the greatest drawbacks of turbine sinking pumps, viz., their inability to run "on snore," *i.e.*, when drawing air.

In an article in the "Iron and Coal Trades Review" of March 29th, 1912, results are given which were obtained with Weise & Monski's turbine sinking pumps when sinking the Britannia pits of Messrs. the Powell-Duffryn Steam Coal Company, Ltd., in South Wales. From this article it appears that in consequence, with a first-class general design, a novel device enabled these pumps to draw air and to "pick up" immediately without repriming after they were practically half-filled with air. This made the pumping such a success that, in spite of an inflow of about 17,000 galls. per hour, the pit in which they were working, and which had a diameter of 21ft., has steadily progressed at the rate of 9 yards per week,

i.e., quite as quickly as the twin shaft some hundred yards away, which happens to be nearly dry. About 90 yards, representing 10 weeks' work, could be sunk without overhauling the pump, in spite of the water containing great quantities of crystalline rock and impurities of every kind. It should be mentioned that this pump was driven by a motor which was connected to the common electric mains of the colliery in the ordinary way. If connected to a separate generator it would probably have been possible to double this period of operation without repair. Though to anybody not acquainted with sinking through crystalline strata 10 weeks may not seem a very long run for the interior parts of a pump, the contractor in that particular case will no doubt confirm that he has never sunk a wet shaft in a more economical manner, for the costs

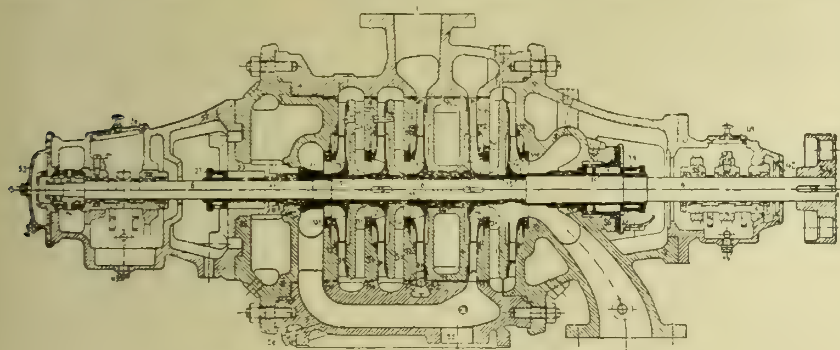


FIG. 27.—WEISE & MONSKI MULTI-STAGE TURBINE PUMP.

of any interruption in the sinking due to the pump would be much more than the money spent on spare parts and repairs.

The question of economy again assumes a radically different form in connection with boiler feed pumps. Besides their great mechanical advantages, viz., absence of shocks, possibility of doing away with relief valves, smallness of space required, and absolute reliability, their economy is nearly always decidedly better than that of steam-driven piston pumps. The reason for this is a thermal one. Steam cylinders working intermittently and at only a few strokes per minute will always act more as condensers than as steam engines, as the inner surfaces are always considerably cooled down before fresh live steam enters the cylinder. On the other hand, the motor of an electric boiler feed pump utilises energy very economically. The only disadvantage on the part of the turbine feed pump is that it is generally not advisable to stop a turbine pump and restart it every few minutes. It is run right through, whether delivering its full or a reduced quantity, or none at all, and regulates itself automatically, because any tapping off at any part of the mains causes the mean pressure to fall off, and therefore the duty of the pump to increase correspondingly, and vice versâ. It is clear that as the duty constantly varies the efficiency will also vary, and it is extremely difficult, if not impossible, to form an exact opinion as to the mean average commercial efficiency which might be expected, though in this instance the commercial and the technical efficiency are coincident. The difference between this mean average efficiency and the guaranteed normal efficiency does not, however, turn the scale of economy in favour of the steam pumping plant.

Fig. 28, for which the authors are obliged to the courtesy of Mr. A. Borsig, Berlin, shows the fluctuations in load, efficiency, power consumption, and boiler pressure for a turbine boiler feed pump for a battery of 12 boilers working under ordinary conditions side by side with a duplex steam pump, both units delivering the same quantity. The Borsig turbine pump had been running for two years when this diagram was taken. The steam consumption of the duplex pump and the amount of current used by the turbine pump were both carefully checked, and the results were:—

Turbine Pump: Produced 10 w.h.p. on the average. Consumed 15·6 kw. on the average.

Duplex Pump: Steam consumption for equal delivery (about 11 i.h.p.), 1,210lbs. of steam per hour.

At these works, a kilowatt-hour (B.T.U.) costs about 0·65 pence, whereas 100lbs. steam can only be generated at a cost of about 1·55 pence. The costs of operation are therefore:—

For the turbine pump, about 10d. per hour.

For the duplex pump, about 1s. 7d. per hour.

It is evident that the mean average quantity to be pumped is of great influence on the economy of a boiler feed pump, and one can generally say: (1) That turbine boiler feed pumps are better suited for feeding batteries of boilers than single boilers, as then the duty is generally equalised. (2) That, if only a part of a boiler is actually operated, the balance being standbys, it will be more economical to install two small turbine pumps for each half of the battery, instead of one large one for the whole battery, as otherwise the pump would, for the greater part of its life, run at a greatly reduced delivery, which would affect the commercial efficiency more severely than the decrease in efficiency naturally combined with a smaller pump.

The A. E. G. Electric Company have recently issued a pamphlet on turbine boiler feed pumps driven by steam turbines, which contains some very interesting figures as regards economy. When comparing the economy of motor and of steam turbine-driven boiler feed pumps it is essential to note the following: The thermal overall efficiency of a steam-driven feed pump is, of course, very high as soon as one utilises the exhaust steam for heating the feed-water in a special heater. Similarly to a steam injector, the steam turbine-driven feed pump converts only about 3 to 4 per cent. of the total energy contained in the live steam input into mechanical energy in the form of water delivered to the boilers. Another 80 or 90 per cent. is utilised for heating purposes and only a balance of about 5 to 10 per cent. is lost. Compared with this, the thermal overall efficiency, *i.e.*, that including the losses by transforming the heat of the steam into the form of electricity for a motor-driven turbine feed pump, is only about 15 per cent., which does not seem very high when regarded from the purely technical point of view. When considering the case commercially, the aspect changes altogether. It must be emphasized that the total amount of energy transformed in a steam turbine-driven boiler feed pump is about five times as great as that used, in the form of electric current, by a motor-driven feed pump. A 50 per cent. loss in the latter plant is, therefore, taken absolutely, no greater loss than a loss of 10 per cent. in the former. Consequently, if in due course, the efficiency of the steam plant, and especially the heater, drops—say, by incrustation of the pipes—each 1 per cent. of decrease has five times as detrimental an effect as when the efficiency of the motor-driven plant drops by the same percentage. The mechanical efficiency of the pumps proper should, by-the-way, not drop perceptibly in many years of running, as they have to deal with the cleanest possible water, and this consideration is corroborated by experience. In the long run the commercial economy of steam turbine and

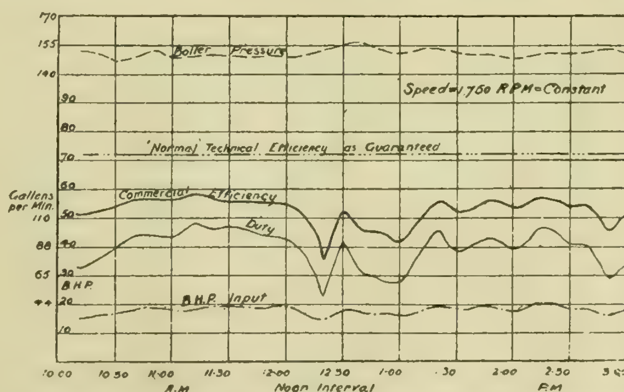


FIG. 28. CURVES SHOWING VARIATIONS OF OUTPUTS OF TURBINE BOILER FEED PUMP UNDER PRACTICAL CONDITIONS.

of motor-driven boiler feed pumps will, therefore, not be so different as to outweigh considerations of a purely practical character, viz., whether it will be more advisable to make the feed pumps dependent on the boiler only, *i.e.*, drive them by steam, or whether the supply of electric current be sufficiently reliable for any emergency so as to justify making the boiler feeding dependent on electric-driven pumps. In any case, where the boiler pressure varies considerably, direct-current motors, or at least variable-speed alternating-current motors, are, of course, advisable. In all cases, however, the greatest indirect economical advantage of turbine boiler feed pumps

over piston feed pumps is to be seen in the fact that no oil is admixed with the feed-water.

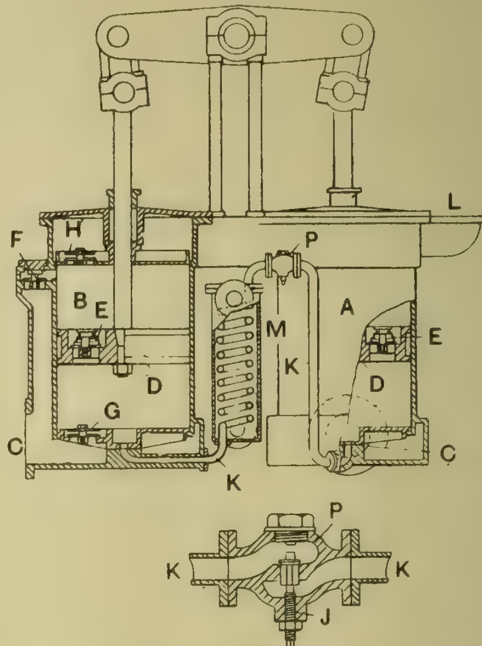
Before concluding their paper the authors would like to again draw attention to the fact that those who declare that either the turbine pump or the reciprocating electric pump are invariably superior as regards over-all economy are wrong. There are a good many instances where a careful consideration of all factors, including maintenance and repair in a capitalised form, will prove the turbine pump to be an easy winner over the electric piston pump, even if the latter has a 12 per cent. or more higher commercial efficiency than the turbine pump. In this connection the authors wish to refer to a comparison carried through by Mr. F. zur Nedden in the article in the May number of the "Engineering Magazine" in 1910. On the other hand, it can equally easily be proved that, *e.g.*, in the case of very small volumes to be lifted to the very high heads the piston pumps will furnish the best over-all economy, as here small technical and commercial efficiency, combined with the comparatively high prime costs and great number of spare parts, count heavily against the adoption of the latter. Of course, the question of the sumps will incidentally play a great rôle in these economic considerations, but it will only be possible to balance the pros and cons on the basis of the special conditions, which are different in nearly every instance.

Only one statement can be made with a fair claim to general correctness, and this is that it seems always advisable, if a spare pumping plant is required, to choose turbine pumps for that purpose, as the three advantages of low prime and maintenance costs and small space required are in no other type of pump combined with such reliability and simplicity as with the turbine pump. It will all the more readily be possible to make a rule of this, as there are scarcely any problems to-day in connection with the lifting of liquid mediums for which the turbine pump has not become adaptable.

ODDIE'S AIR PUMP.

AN arrangement of combined wet and dry air pump for use with condensers, the invention of Mr. P. F. Oddie, St. Albans, the Ridgeway, Wimbledon, is shown in the accompanying sectional views. In this arrangement two separate cylinders are used whose piston rods are so connected that the piston of one pump cylinder is making an upward stroke while the piston of the other is making a downward stroke, the one cylinder acting as a so-called wet air pump and the other as a so-called dry air pump. Referring to the illustrations, A is the wet air pump cylinder and B is the dry air pump cylinder. Each cylinder is provided with a suction opening C communicating with the condenser, so arranged that the condensed water flows into the wet air pump cylinder under the foot valves, while air alone passes into the chamber below the suction valves of the dry air pump. Each cylinder is fitted with a piston D, having valves E loaded with springs, and in addition to the ordinary suction and head valves G and H auxiliary suction valves F are provided in order that air may be drawn in during the greater part of the down stroke as well as during the whole of the up stroke. The piston rods of each cylinder are so connected together by means of a beam that when one piston is descending the other is ascending and vice versâ. A pipe K connects the bottom of the barrel of the wet air pump with the bottom of the barrel of the dry air pump. This pipe passes through a cooler M and is formed as a coil so as to present a large cooling surface to the circulating water or cooling mixture in the cooler M, which enters at the bottom and is discharged at the top. The pipe K is provided with a valve P, an enlarged section of which is shown.

In operation, as the dry air pump bucket ascends and the wet air pump bucket descends, water will pass from the wet air pump barrel through the pipe and coil K into the dry air pump barrel, being injected into the latter by the difference of pressures in the two barrels during this operation and being cooled by the circulating water in the cooler M. On the return stroke, that is to say, when the dry air pump bucket is descending and the wet air pump bucket is ascending, the tendency will be for the water to return through the pipe from the dry air pump barrel to the wet air pump barrel since, owing to the loaded valves in the buckets, the pressure under the dry air pump bucket will be in excess of the pressure under the bucket in the wet air pump. With each change of stroke, therefore, water passes to and fro in the pipe K, is cooled and injected into the dry air pump cylinder, and by making this pipe and coil of sufficient capacity the dry air pump cylinder may be cooled to any desired extent, without affecting, however, appreciably the temperature of the condensed water delivered by the wet air pump. Further, it will be observed that this cooling injection water being taken from the under side of the bucket of the wet air pump and being here under a vacuum, is practically free from air, and as it is never exposed to a pressure greater than that due to the loaded valves in the bucket, which amounts to about one-third of atmospheric pressure, it can never pick up or retain much air before being



ODDIE'S AIR PUMP.

injected into the dry air cylinder, hence the loss of efficiency due to injecting water for cooling purposes which has been exposed to and contains air at atmospheric pressure is avoided.

The valve P is so constructed that the amount of water that shall pass back from the dry air cylinder to the wet air cylinder can be regulated by means of the spindle J which holds the valve off its seat, thus allowing a certain amount of water to pass back from the cooler to the wet air pump. In practice it is found that the best results are obtained when only a small quantity is allowed to pass back in this manner, whilst the larger portion passes through the bucket and head valves of the dry air pump. The discharge from the dry air pump may be taken away separately from that of the wet air pump or may be discharged with that of the wet air pump, through a common delivery pipe L.

Personal. — The directors of the Vulcan Boiler and General Insurance Company, Ltd., have received, with regret, the resignation, as chief engineer, of Mr. J. F. L. Crosland, M.Inst.C.E., who, owing to advancing years, has felt bound to retire from active participation in the life of the company he has served with so much devotion. He joined the engineering staff of the Vulcan in 1863, when the business of boiler inspection was still struggling for its existence, and he has had the great satisfaction of seeing that business firmly established and the Vulcan Company rise to be the largest independent engineering inspection and insurance organisation of its kind in the world. Mr. Crosland will retain a connection with the Vulcan Company as consulting engineer, and his countless friends will join in wishing him many years in which to enjoy the rest he has earned so well. Mr. C. Bullock, Wh.Sch., A.M.Inst.C.E., has been appointed chief engineer in succession to Mr. J. F. L. Crosland. Mr. Bullock joined the engineering staff of the Vulcan in 1876. He was appointed chief assistant engineer in 1888. He is the patentee of various specialities connected with the maintenance and safer working of steam boilers, all of which have been acquired by the Vulcan Company. Mr. J. C. H. Crosland, A.M.Inst.C.E., and Mr. F. H. Bullock, A.M.Inst.C.E., have been appointed assistant engineers.

MANUFACTURE OF OPEN-HEARTH STEEL WITH REFERENCE TO IMPROVEMENT IN YIELD.*

BY F. W. PAUL.

In the early practice of open-hearth steel it was not unusual to obtain yields of 100 per cent. as an average of 12 months' work. During the interval it has been the invariable practice when rebuilding the older small furnaces, or when installing new plant, to erect furnaces of considerably increased capacity, so that, whereas in 1880 they were about 10 tons, they are now 40, 80, and 100 tons.

The author frankly admits that some of the important reasons which influenced him in his own practice to increase the weight of charges and the size of furnaces were the reasonable anticipation of increased yield, resulting from smaller percentage of waste ingot butt ends, less incidental scrap from furnaces and ladles by reason of fewer number of charges; and also the expectation of less waste due to accelerated melting, as the large chambers can maintain a greater intensity of combustion throughout the whole period of charging and melting. The experience of working with large furnaces during the past 10 years affords reliable data as to the yield, which may be taken at 94 to 95 per cent.

It will be instructive to enquire into the causes of greater metallic waste in large furnaces, with view to improvement, and with this object the author proposes to review in detail the operations of open-hearth steel manufacture, and to give particulars of a new method of conducting the pig iron, scrap, and ore process, which, in a few practical trials in 80-ton furnaces, has given increased yields of 5 to 7 per cent. With a view to reliable and accurate weighings, the pig iron, steel scrap, and ingots were weighed in bulk in trucks on machines. The amount of ore used was 50 per cent. greater than in ordinary practice, and this additional data, coupled with a balance-sheet of the amount of metallic iron charged into the furnace, and also the weight and composition of tapping slag, fully confirms the accuracy of the weighings, and the big increase in yield of ingots. For the purpose of comparison, the following table shows approximately the respective bath areas of melting furnaces from 1880 to 1912:—

Year.	Weight of Charge.	Length between Blocks.	Width inside Linings.	Bath Area.	Area Ratio per Ton.
	Tons.	Feet.	Feet.	Square Feet.	Square Feet.
1880	10	14	10	140	14·0
1890	25	21	11	231	9·2
1900	40	26	12	312	7·8
1912	80	35	14	490	6·1

The area ratio per ton of charge has gradually decreased from 14·0 sq. ft. to 6·1 sq. ft. The practical limit of width of furnace between linings is reached at about 14ft., because, if made wider, the cost of roof repairs would be greatly augmented, therefore, if it were desired to have an 80-ton furnace, with bath area ratio of 14 sq. ft., it would require to be 80ft. long. Between the range of 35ft. and 80ft. there is ample choice, but this point is referred to merely in reference to bath area, and its bearing on waste of metallic charge during period of melting and silicon elimination. Any detailed criticism as to within what limits the critical point may be said to be reached in the length of modern large furnaces would have to be dealt with in a separate paper.

It is obvious that a large furnace with reduced bath area ratio, coupled with the necessity of having a good inclined slope in the bottom to drain the metal and slag completely from the extreme ends to the taphole, results in working with a deeper bath of metal as compared with the shallow bath of small furnaces, and the author suggests this is one of the indirect causes of less yield. In order clearly to differentiate between the author's new method and the present-day ordinary practice, it is advisable to compare under the following heads, viz.: (1) Theoretical yield; (2) charging; (3) melting; (4) elimination of silicon; (5) boiling.

* Paper read before the Iron and Steel Institute, October, 1912.

ORDINARY PRACTICE.

Theoretical Yield.—The initial charge may be all pig iron or various proportions of steel scrap, such as:—

	Y.	Z.
	Per cent.	Per cent.
Pig iron	100	60
Steel scrap	nil	40
Totals	100	100

Average composition of initial charge:—

	Y.	Z.
	Per cent.	Per cent.
Iron	92·5	95·3
Carbon	3·5	2·1
Silicon	2·5	1·5
Manganese	1·5	1·1
Totals	100·0	100·0

Theoretical yield on complete reduction of the oxide of iron in the ore:—

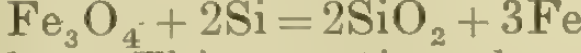
	Y.	Z.
	Per cent.	Per cent.
Iron	92·5	95·3
Carbon	10·9	6·5
Silicon	3·3	1·9
Manganese	0·7	0·5
Yield	107·4	104·2
Yield ordinary	95·0	95·0
Difference	12·4	9·2

Notwithstanding the greater theoretical yield in working all pig iron charges, it is found in practice there is very little difference, because of the waste of metallic iron which takes place during silicon elimination, and, as the total time occupied in working such charges is much longer, it is more economical to work with a proportion of steel scrap.

Charging. — Numerous variations in detail have been tried from time to time to minimise waste of oxidation during melting, such as charging the scrap first and covering it with the pig iron; charging all the pig iron, and when melted charging in the steel scrap; but in the ordinary pig and ore process, with, say, not less than 50 per cent. of pig iron, the latter has always been found quite impracticable, owing to it either setting the pig iron or losing much time.

Melting. — The heat of the flame is conveyed by direct contact to the upper layers of the charge, but in large furnaces of small bath area ratio the heat is to a larger extent conveyed by conduction to the lower layers of a deep bath. There is ample heat energy stored in the chequer work of large furnaces to maintain such intensity of combustion during the melting period that the heat cannot be conveyed quick enough by conduction, so that even whilst some of the lower layers of metal are solid, the upper layers are exposed to the keen flame temperature with intense local oxidation. The ready command of high-flame temperature may even cause volatilisation of the iron before the whole mass of metal is melted. The author is of opinion this is one of the causes of greater waste in large furnaces with large chambers and good gas.

Elimination of Silicon. — When the charge is thoroughly melted, and not too hot, the reaction of



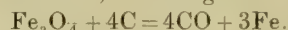
$$Fe_3O_4 + 2Si = 2SiO_2 + 3Fe$$

takes place quietly. This reaction, however, is at times seriously retarded when the bath of metal is too hot, more particularly when using very grey pig iron containing a high percentage of silicon, or with charges containing a small percentage of steel scrap. In large deep furnaces with big chambers, the temperature of the metal may be unequally distributed, that is, the upper layers too hot. Under these conditions, instead of the reaction taking place quietly, there ensues antagonistic action between the metal and oxide in the slag, causing them to froth up, and at times to overflow the sill plates. It is at such times that the banks of the furnace are fluxed away, and this is the principal cause of delays for repairs.

Again, this forced reaction of silicon elimination, or, as it is practically termed, "forcing on the boil," results in subsequent "sluggish boil"—that is, not boiling freely from the bottom, and the steel is not of thorough uniform composition. In bad cases this is evidenced by the scintillations or sparks from the highly-carbonised metal, which at first runs out of the furnace when it is tapped. This reaction is accompanied by emission of dense volumes of brown smoke, which are carried away with the waste gases to the chimney, and are identical in composition with the fumes of the afterblow in Bessemer practice. These oxide of iron fumes in their passage through the chambers become partly deposited in the chequer work as fine dust, and are the means of causing the objectionable fluxing action and slag deposition, more particularly in chambers of large capacity and high temperature.

Boiling. — The ebullition at this stage is caused by the escape of carbon monoxide, resulting from the reaction

$$Fe_3O_4 + 4C = 4CO + 3Fe.$$



Unlike the silicon reaction, the affinity of oxygen and carbon is augmented with increase of temperature, therefore the nearer the furnace is worked to its practical maximum intensity consistent with utilising the heat with regular feeding of iron ore, the more the boiling is accelerated and the period shortened.

Proposed New Method of Charging and Silicon Elimination.

Charging. — Instead of the pig iron being charged in one continuous operation, only a small fraction is taken, about 5 to 10 per cent., and brought to a molten state, and thereafter the subsequent additions of pig iron are charged into this initial bath of molten metal, which is maintained in liquid form substantially during the entire period of charging. After the pig iron is all charged, and the silicon sufficiently removed to permit of superheating the metal without loss, or after the metal has been brought to the boil, the steel scrap is charged in such increments and at such rate as is commensurate with the heating capabilities of the furnace maintaining the bath in liquid form.

As regards the use of molten pig iron in basic or acid furnaces, this method of dealing with fractions of the charge pari passu, with additions of iron oxide, permits of the elimination of silicon at low temperature, and so avoids the fluxing of the banks, and thus affords, in the basic process especially, means of working with low sulphur pig iron, and greater latitude as regards contents of silicon.

Melting. — The heat of the flame is in direct contact with each successive addition of pig iron and scrap floating on the surface, consequently the gas and air can be maintained at their maximum, and the temperature of the furnace and metal regulated by the rate at which cold material is fed into the furnace. The pig iron and scrap floating in a molten bath of metal with a protective coating of slag are protected from the oxidising atmosphere of the furnace. Less waste ensues, and the yield is increased.

Elimination of Silicon.—Another important feature of this method is the practical means of arranging the most suitable conditions for removal of silicon, and obtaining its equivalent reduction of iron from iron ore without diminishing the number of charges per week. Snelus demonstrated in 1871 that at the initial low temperature at the commencement of the Bessemer blow, silicon was oxidised whilst leaving the carbon intact. Bell also demonstrated in 1871 by his washing process, that the intimate contact of molten pig iron and molten oxide of iron resulted in removal of silicon whilst the carbon was not affected.

The reaction of oxide of iron and silicon was expounded by Snelus in his report on the Danks puddling process.* Dr. Stead has confirmed by experiments that, under suitable conditions, the reaction of oxide of iron and silicon results in an increase of yield. Particulars of those experiments are reported in the "Proceedings of the Cleveland Institute of Engineers," 1896. He pertinently puts the question, "Why do we not as a rule get an increase of yield on the metal and scrap charged into our open-hearth furnaces?" He says the first answer is, because there is a very heavy waste on melting the scrap, and secondly, because it is highly probable that the metalloids do not always completely reduce the oxides to the metallic state.

*"Journal of the Iron and Steel Institute," 1872.

Whilst the author is in agreement with these views, he desires to point out that, in addition to avoiding the waste during melting to which Dr. Stead refers, it is also necessary to prevent the great waste which takes place during silicon elimination. As a result of practical trials of the proposed new method, it has been conclusively proved that the actual theoretical yield can be more nearly approached than has ever hitherto been accomplished by the ordinary process.

In the Bessemer process, when a very siliceous pig iron is used, the reaction between the oxygen and silicon results in the metal becoming so hot that the carbon can be entirely eliminated, whilst there still remains as much as 1 per cent. of silicon unoxidised in the steel, which can only be eliminated by an afterblow, with great waste of iron and emission of dense volumes of brown smoke.

The usual practice when it is recognised the metal is too hot is to add cold steel scrap. In the puddling process it is also recognised that siliceous iron causes trouble, frequently resulting in the metal cutting through the bottom plates of the furnace. A grey pig iron, such as Nos. 1, 2, 3 hematite or Cleveland, may be described as containing silicon and other metalloids in such quantity that the carbon cannot all exist in the combined form.

In the Talbot process, molten pig iron is charged into an open-hearth furnace, containing 50 tons, more or less, of steel. It is evident the mass of steel is necessarily at a high temperature, so that with suitable iron containing small percentage of silicon, there immediately ensues a vigorous reaction between the oxide of iron and the carbon. When, however, grey siliceous iron is used, there ensues a violent and explosive action, accompanied with the emission of dense brown fumes. The probable explanation is that, as already pointed out, it is impossible to superheat grey pig iron without oxidising the iron. It is interesting to note that Mr. Talbot obtained a patent in 1909 for preparatory treating of grey iron in a Bessemer vessel for its subsequent use by the Talbot process. In the patent specification he says: "One of the advantages of this treatment is, that all, or practically all, the carbon remaining, of which about 1 per cent. was originally in the graphitic form, is converted into combined carbon, and the foaming, or even the explosions, due to the graphite form of carbon in the subsequent treatment is avoided." Apart from considerations of added cost of dual processes, the necessity of silicon elimination from grey pig iron in a Bessemer vessel sacrifices part of the theoretical yield, and in so far defeats the raison d'être of the 1890 Talbot patent. The violent reaction in the Talbot process would appear to be identical with what takes place in ordinary open-hearth practice when siliceous pig iron of the charge is allowed to get too hot before the silicon is eliminated.

Having pointed out the practical disadvantages attending the elimination of silicon at high temperature, it will be now pertinent to explain in detail the conditions of its removal in the proposed new method. During the additions of pig iron as described under heading (Charging), oxide of iron is added in sufficient quantity to eliminate the silicon. By this means the melting stage and the silicon elimination stage are merged into one. It was pointed out under heading (Melting) that the temperature of the furnace and the metal could be regulated by the rate at which cold pig iron was added; that is to say, advantage can be taken of the furnace working at full speed and having the means of preventing the temperature of the metal rising very little above its normal melting point. The elimination of silicon is carried on concurrently with melting, that is, for a period of six hours or more with the metal at low temperature, therefore the scouring action on the banks is considerably diminished.

This new method of bringing each successive addition of pig iron, which is melted whilst floating in contact with the oxide of iron in the slag, is a near approach on a practical scale to the ideal of bringing in close contact each molecule of silicon and oxide of iron, so that by the time the pig iron is all charged the silicon has been more or less eliminated under the most favourable conditions, viz., intimate contact of the pig iron and the oxide of iron in the slag, the temperature of both being under such perfect control that the reaction takes place without any emission of brown smoke.

In the pig iron and ore process, in which the initial charge contains not less than 50 per cent. of pig iron, it has hitherto been impracticable to superheat the pig iron in the furnace

preparatory to subsequently feeding the steel scrap. The author ventures to assert that it is quite impracticable to do so with siliceous grey pig iron in an open-hearth furnace to such an extent as to enable steel scrap to be immersed into it without very serious delay and waste.

The author suggests the limit of superheating siliceous iron is reached when the iron begins to be volatilised, or at least carried off in the form of brown fumes, so that any prolongation of maintaining a higher temperature in the constructional brickwork of the body of the furnace would not result in the metal taking up much more heat, but merely result in the slag becoming so enriched with oxide of iron that the banks of the furnace would be cut away.

In the proposed new method, the ideal object aimed at is that the silicon should be more or less completely eliminated by the time the pig iron is all charged, or previous to charging the steel scrap. Such metal, that is containing little silicon, can be superheated until the temperature suffices for the reaction of the oxide of iron from the ore and the carbon in the metal, and the charge would come to the boil, provided the slag contained sufficient oxide of iron. On the other hand, if the slag were allowed to thicken up towards the end of the silicon elimination stage, the bath of metal could be superheated to a very considerable extent.

Boiling. — Same remarks as in the ordinary process, with the exception that, by reason of the very thorough elimination of silicon, the boil will be more open or vigorous and the metal in better circulation, thus enabling the heat to be conveyed quickly to the metal, and the duration of the boil shortened.

The following are the important features of these proposals in method of working, which have been definitely confirmed by actual practice in 70-ton furnaces: (1) A very decided increase of yield. (2) The practicability of superheating the desiliconised metal to such an extent as to permit of cold steel scrap being charged into the bath of metal without partly setting it, and without delay or waste. (3) That charges of all pig iron can be worked with considerable increase in yields compared with charges of pig iron and scrap, and with approximately the same number of charges per week. (4) The brickwork of the furnace is not subjected to such extreme fluctuations of temperature. The free unobstructed passage of the flame is not so destructive to linings and roof as when the flame is deflected by striking against piled-up material in the furnace. (5) During the melting stage and silicon removal at low temperature the level of the metal in the furnace is continually altering, therefore the scouring or fluxing action on the thin top part of the banks of the furnace as in ordinary practice is avoided, consequently there is less loss of time for repairs and less risk of breakouts, which are of greater importance in large furnaces. (6) The author has on a previous occasion referred to an investigation which showed that metallic iron was wasted to the extent of 25 cwts. per hour by passing up the chimney as brown oxide of iron fumes during the silicon removal stage. As this takes place for two hours during every charge, and say 400 charges are worked per year, there would be an equivalent of 1,500 tons of oxide of iron passing through the chambers per year. Part of this settles out, and is deposited in the gas and air chambers, to which he has referred. It can readily be conceived that the ability to prevent the oxide of iron fumes being formed will probably result in the life of the chambers being increased to as long again.

Fatal Hoisting Accident.—The Newcastle City Coroner held an inquest on the 25th ult. on the body of a fitter who was killed as the result of a hoisting accident at the Elswick Works of Messrs. Armstrong, Whitworth, & Co. At the time of the accident deceased was removing with block and tackle a "dummy" torpedo. The "dummy" would weigh about a ton, and there were two guide ropes. Deceased was at the rear end rope when the sling rope broke and one of the torpedo blades struck him on the forehead. The sling had only been used about 20 or 30 times. The Factory Inspector, in his evidence, stated that the splicing on one of the ropes was defective. A slinger who made the sling for the torpedo shed said he did not examine the slings in the torpedo shed before they were used, nor was it his duty to examine them periodically. The Coroner said it would be advantageous if slings and implements used for lifting heavy weights were examined periodically. The usual verdict of "Accidental death" was returned.

TESTS OF WHITE METALS.

At the recent meeting of the International Association for Testing Materials Mr. N. Pecoraro read a paper entitled "Tests of White Metals," in which he recorded the results of a large number of tests of these metals. Among the alloys which are utilised in engine construction, the so-called anti-friction alloys claim, he says, a particular importance. Most of these alloys contain as chief constituent tin which is mixed with antimony, copper, sometimes with mercury and with small quantities of lead. Not rarely we find alloys whose chief constituent is lead, and finally in isolated cases such which largely consist of zinc.

When making a choice of an anti-friction metal, we have to regard the specific stresses to which it will be exposed, the speed of the surfaces under contact, the manner of lubrication, the more or less great likelihood of shocks, &c. We have further to consider the suitability of the material for diminishing friction, its easy applicability, the capacity for adapting itself to diverse shapes—the latter because the metal must fill the journal bearing—the resistance to wear, the expense, &c. Such a selection can only be made on the strength of the results of experiments which must not only be very numerous, but which are also, from their nature, very difficult to conduct. The performance of these experiments requires very expensive machines with which every workshop is not suitably provided. For this reason the choice of the quality of a white metal best suited for a particular purpose is often taken merely at the hand of experience, which has sometimes caused disappointments in subsequent experiments. As a result of his experiments the author draws the following conclusions:—

(1) The temperature at which an anti-friction metal is fused may exercise an important influence upon the behaviour of the metal with regard to the coefficient of friction which would, under otherwise equal conditions, become apparent under application. In order that an anti-friction alloy may in practice give constant results under the same conditions, it should not only be prepared always by the same method, but it is also necessary that its fusion takes place at the temperature at which the alloy shows the most favourable behaviour. It need not be mentioned that this holds not only for practical application, but also for any preparation of specimens for laboratory tests.

(2) The hammering to which anti-friction metals are frequently submitted after having been poured into the bearings has, as a rule, an influence upon the friction which is not unimportant; in most cases this influence is not favourable.

(3) Of the acceptance tests of white metals, the compression tests appear suitable for arriving at an estimate as to how far the respective metal will be able to satisfy the conditions of compression without undergoing any practically inadmissible deformation.

(4) Abrasion tests appear always most desirable, since the resistance to abrasion is an important characteristic of anti-friction alloys. These tests are, however, neither easily conducted, nor can they rapidly be carried out. It would therefore be advantageous to substitute for them some simple experiments which would likewise enable us to make a comparison between different alloys as regards their resistance to abrasion. The hardness test by the Brinell method constitutes such an expedient. Further experiments to elucidate this matter more fully is desirable.

(5) The determination of the hardness number of anti-friction alloys of equal chemical compositions may perhaps supply us with the possibility of establishing a comparison in broad features between the different alloys as to their suitability for diminishing friction. If this should be confirmed the exact determination of the average hardness numbers of anti-friction alloys would acquire an extraordinary importance, because it would in many cases enable us to arrive at a quick estimate in place of the tedious, expensive, and difficult friction test, for which, moreover, suitable arrangements are not always available.

(6) Apart from the impact tests which sometimes yield useful information with regard to the impact strength of anti-friction alloys, as well as from the compression and hardness tests, useful information concerning the most important characteristics of those metals cannot be obtained from other mechanical tests (tensile and bending tests, &c.), to which such metals are occasionally submitted.

MODERN DEVELOPMENTS IN THE ELECTRO-DEPOSITION OF METALS AND ALLOYS.*

BY GEO. P. LEE.

HITHERTO electro-deposition has been resorted to mainly for decorative purposes; that is on an article made of common metal or alloy to deposit one with a greater surface brilliance. But the process can now be applied not only for such ornamental work, but to overcome some of the many difficulties that confront marine engineers. That one metal could be coated on to another by dipping in suitable solutions was known to the ancients, and the Greek historian Zosimus in the fifth century described how swords and shields were so coated with copper. The same effect was described as the actual transmutation of metals by Paracelsus in the 16th century. Probably the first commercial instance of one metal being used to coat another was in 1742 when Thomas Bolsover by welding silver on to a copper foundation established the now extinct industry of Sheffield plate manufacture. The process was entirely mechanical and consisted of welding and rolling thin silver sheets to a thicker copper one. Various articles such as trays, teapots, candlesticks, &c., were made from the sheets so treated, and had therefore all the appearance of silver, although the bulk of the metal was copper. The industry attained considerable importance until the advent of electroplating. As this does the same thing in a much better and cheaper way the manufacture of Sheffield plate is no longer practised.

The first attempt at electrolysis or analysis of a liquid by an electric current was probably by Dieman and Paets or by Van Trootswyk, who in 1789 at Haarlem decomposed water by electricity. A little later Ritter precipitated silver by the same means. This was in the early days of electrical development and when only frictional machines giving a very high voltage and a very small current were available, and these, as we now know, are not the conditions generally necessary for electrolytic work. In 1800 Volta's pile was introduced, and as this gave a very large current with a low voltage the way was opened for further development in electrolytic work. The most important was the brilliant electro-chemical discoveries of Davy, who, by decomposing the oxides of the alkalies and alkaline earths, proved that these were not elementary substances as had hitherto been thought, but the oxides of the metals lithium, sodium, potassium, &c., which metals he for the first time separated from their compounds. In 1801 Wollaston deposited copper on silver and in 1803 Cruickshank deposited several metals from their solutions. Wollaston obtained his deposit by inserting the silver in contact with a more oxidisable metal in a solution of copper, thus making a small battery of the solution itself. Cruickshank had constructed a battery of considerable size for his experiments. In 1805 Brugnatelli deposited gold on to silver medals. The researches of Oerstad and Arago, the construction by Faraday in 1831 of the first magneto-electric machine, the invention by Pixii in 1832 of the prototype of the modern dynamo and the introduction of Daniell's battery, besides giving fresh sources of electrical energy, widened the interest in electrical work. In 1836 De la Rue noticed that the copper which deposited on the cells of a Daniell's battery exactly reproduced every line or mark on the surface on which it is deposited, but he failed to appreciate the possibilities of this discovery. Three years later three men—Jacobi in St. Petersburg, Spencer and Jordan in England, independently and almost simultaneously described the process of electrotyping. In 1836 Elkington obtained a patent for gilding copper and brass objects, and in 1838 one for zinc plating by a method similar to Wollaston's. Spencer in describing his electrotyping process also stated that non-conducting substances, such as wood and plaster of Paris, could be made conductive and covered electrolytically if they were first covered with a film of bronze powder; and in 1840 Murray discovered that moulds of non-conducting material could be made conductive by brushing them with plumbago, so that metallic moulds were no longer essential.

In 1840 Wright after experimenting with many solutions discovered the use of the cyanide bath for the production of good deposits of gold and silver. No good results had before this been obtained in depositing these metals, because the few salts that are soluble gave very poor deposits, for as gold and silver are electro-negative to most ordinary metals they are easily thrown out of solution by the other metals. Good deposits are seldom obtainable by this "simple immersion" method. Solutions of the double cyanides of potassium and gold or silver, however, permit of good electrolytic deposits. This solution was patented by Messrs. Elkington, and from this time onward the industry of silver plating became firmly established and completely superseded Sheffield plate.

But though the development of dynamo-electric machinery and other branches of electricity has advanced by leaps and bounds, but very little further progress has been made in electro-plating. Indeed it can be safely said that the industry is practically limited to the electro-deposition of gold, silver, and nickel. Copper is deposited on to iron before nickel plating and brass is also deposited, but most of the attempts to deposit metals on to iron or steel have not been very successful.

Many theories had from time to time been advanced to account for the phenomena of electrolysis, but interesting though it might be to trace the developments through the theories of Davy, Berzelius, Faraday, Grotthus, Clausius, &c., it is beyond the scope of this paper. The laws stated by Faraday are still found to be true, namely: (1) The quantity of an element set free or deposited by an electrical current is proportional to the strength of the current and the time. (2) The amount of an element set free or deposited is proportional to its chemical equivalent. These two laws may be

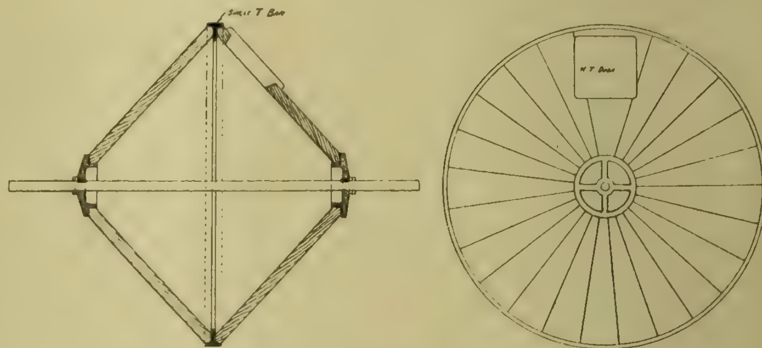


FIG. 1.—GALVANISING DRUM.

combined in one as—The same quantity of electricity (in coulombs or ampere hours) passing through an electrolyte sets free deposits, or transfers to other combinations, always the same number of valencies.

The theory now generally accepted, and known as the dissociation theory or the theory of ions, was first enunciated by Arrhenius in 1887, following up valuable work done by Van't Hoff. This theory was foreshadowed by Faraday and the terms used in explaining it, such as ion, kation, anion, &c., were due to him. Briefly this theory states that all electrolytes (according as they are good or bad conductors) are more or less dissociated or broken up in solution into ions carrying positive or negative charges of electricity in proportion to their valency. These ions are in a state of continual motion, migrating to every part of the solution, and the electric current simply acts as a directing force causing the ions to migrate in a definite course to each electrode and there to deposit their electric charges, after which they appear as the usual chemical elements or groups, and may be set free as such, or undergo further chemical decomposition with the electrode or solution. The latest theories deal with the extension of the dissociation theory, owing to the conception of the materialistic nature of electricity.

There are many difficulties to be overcome in the deposition of zinc, and in depositing any metal on to iron and steel, and many attempts have been made to overcome them. Attempts have been made to deposit zinc from a zinc sulphate solution by using insoluble anodes of lead and neutralising the acidity of the solution, and at the same time regenerating it by pumping it through filter beds of zinc dust. Zinc dust is a by-product of zinc distillation, and contains both zinc and zinc oxide. It is cheap, but being a by-product, its constituents cannot be guaranteed, and the percentage of zinc may vary from 5 to 80 per cent. It is therefore extremely difficult to arrange that the solution will be so regenerated that no free

* Abstract of paper read at the exhibition of the non-ferrous metals, Agricultural Hall, London, N., June 22nd, 1912, and reproduced from the "Transactions of the Institute of Marine Engineers."

acid is ever in contact with the iron kathodes. It has the further disadvantage that on the surface of the lead anode peroxide of lead is formed, and this sets up a considerable back electromotive force, so that a high voltage is required to overcome it.

A new solution, the invention of two Italian electro-chemists, Messrs. Marino, father and son, and with which the present author is connected, overcomes practically all the difficulties of depositing metals and alloys on to iron and steel in a very simple way. The solution is prepared by dissolving equal parts (about 5 per cent. of total solution) of sodium boroglyceride and sodium borobenzoate in water, and adding the required salt or salts of the metal or alloy. Sodium biborate or borax is familiar to engineers, for it is extensively used in welding, brazing, &c., because of its property of dissolving metallic oxides. It has, however, not hitherto been applied to do this in electro-plating solutions, because it unfortunately also has the property of being decomposed by metallic salts. Prepared according to Messrs. Marino's method with glycerine and benzoic acid, it is not affected by the metal salts, and retains all its power of dissolving metallic oxides. If iron has to be coated with any metal such as zinc, tin, lead, copper, or alloys, this solution not only does not attack the iron, but if there is a film of oxide formed after the iron has been cleaned the solution will remove this, so that the deposit is on to a clean metallic surface, and perfect adhesion obtained. The glycerine, besides preventing the borax being decomposed, has several valuable properties of its own. It mixes thoroughly with water in all proportions, and 100 parts of glycerine will dissolve 50 parts of borax. It prevents the formation of metal hydrates, and thus keeps the anodes in a soluble condition; it is not decomposed by an electric current of the voltage usually used in electroplating, so that a deposit can be forced into recesses and hollows without the risk of decomposing the electrolyte; and it further gives metallic deposits that are reguline, ductile, and adherent. It is evident, therefore, that this solution overcomes all the difficulties of depositing metals, particularly on to iron and steel, in a very simple and inexpensive way

Besides the solution, the mechanical details of electro-plating have also been open to considerable improvement. For ordinary silver-plated ware the original methods of suspending the articles by wires from the kathode rod is still the one usually practised. But for dealing with iron articles that have to be coated with zinc, copper, brass, nickel, &c., this method is too slow and cumbersome, and various mechanical devices have been introduced to save the loss of time and money in wiring up articles. Revolving plating barrels have the advantage that articles are polished by rolling over each other at the time they are being electro-plated. But in the author's opinion these barrels have the defect that a perforated barrel, made of some non-conducting material, is between the anode and the work or kathode. This means that the process of deposition is slow and a considerable amount of power is lost in getting the current through all the obstructions.

Figs. 1 and 2 show the construction of a plating apparatus designed by the author for zinc plating, and Figs. 3 and 4 show the general arrangements of these barrels for cleaning, plating, washing, and drying. Fig. 1 shows the simplest form of the apparatus. It consists of a tee iron ring about 5ft. diam., on which is formed the two cone-shaped wooden portions. One end of the wooden staves butts into the angles of the tee iron, and the other end butts into angles in a spider frame carried on the central shaft. One of these spider castings butts against a collar on the shaft and the other is set up by a nut on the shaft which thus forces the whole structure firmly together. The flange of the tee iron extends about ½in. beyond the wood into the interior of the barrel, and forms the kathode connection, a brush pressing against it conveying the current from the work inside. The anodes are hung inside on the shaft which forms the conductor carrying current to the anodes. As the barrel revolves the work is carried partially round till gravity brings it back; the cone-shaped sides ensure that the articles do not merely slide back but are turned over each other, so that fresh surfaces are continually being exposed.

Fig. 2 is a modification of the first design; a parallel part between two tee iron rings allowing more work, such as bolts, &c., to be put in the barrel. In this design also the shaft is made a fixture, and the barrel allowed to rotate on it. This is to allow the anodes to be fixed in their proper positions and to permit of a non-conducting hood being fixed over them, so that, if by any chance, some of the work is carried round too far, it will not fall across the anode and cause a short circuit. Barrels made on this principle allow the current to be carried to the anode and back from the kathode with the least possible loss, since its path is as short and direct as it can be, and there is no obstruction between the anode and the work. Arranged as shown in Figs. 3 and 4, work can be handled with the minimum of labour and trouble. Starting from the top platform it is put into the top barrel for cleaning. This may be done electrolytically, in a potash solution, with sand, &c., or in whatever way the class of goods require. When the cleaning is completed, the door of the barrel is opened and the work and solution allowed to slide out on to an inclined shoot. Part of this shoot is arranged to turn up and act as a stop, keeping the work on the perforated part of the shoot till all the solution drains off into the tank below. From this tank the solution is pumped up to a storage tank above, passing first through a filter which removes all scale, dirt, &c. From the storage tank the cleaning solution is led back to the top of the barrel, ready to be let in when a fresh supply of work is put in. When the work already cleaned is sufficiently drained, the hinged stop is turned down and the work allowed to slide over it to a second similar stop. In this position the work is under jets of water which thoroughly wash away all dirt and traces of the cleaning solution to the tank below. After this is finished, the second stop is turned down to guide the work into the next barrel, which is the plating barrel. When this has received the work, the door is closed and the barrel started rotating till sufficient deposit is obtained. The door is then opened and the work allowed to slide out and drain as before, then to slide down into a tank of hot water. From this an inclined elevator lifts it out, and draining it, discharges it on to a conveyer which carries it over jets of hot air. This ensures the work being thoroughly washed and quickly dried, for this is necessary if the deposit is to retain its good colour. The solution from the plating barrel is also pumped to a storage tank above and filtered. The complete arrangement enables a large variety of iron and steel goods to be easily and satisfactorily handled. The solutions being constantly filtered are always in an efficient condition. This filtering is very necessary with revolving plating barrels because pieces of metal, scale, &c., are liable to be rubbed off even after passing through the cleaning barrel.

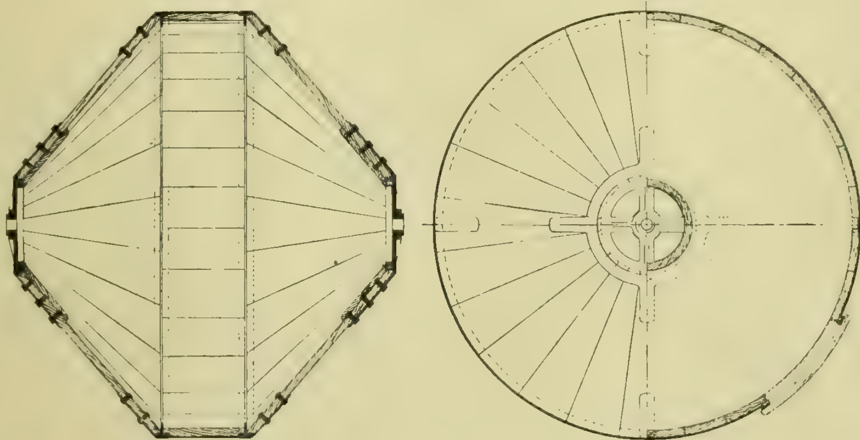


FIG. 2.—VIEWS OF RUMBLER, 5FT. DIAMETER.

It is obvious that all classes of goods cannot be handled in these revolving barrels, for there is a limit to the size and weight that can be safely dealt with in them. For work that is too heavy or too big for the barrel method, the author has designed another arrangement. This consists of vats or baths, 30ft. to 40ft. long, for cleaning and for plating. The baths are provided with endless chain conveyer gear which carry the work along the kathode connection between rows of anodes. The work as it moves along is made to rotate by a toothed

wheel running in a rack. This rack is staggered first on one side and then on the other of the toothed wheel, so that the work rotates first in one direction and then in the other. This ensures that every part of the work will receive a proper coating. The work travels through the bath at such a rate that when it has travelled from one end to the other it has received a proper coating. This method thus ensures that all articles will receive the same amount of deposit if sent through at the same rate. The first two anodes are supplied by a separate dynamo at a higher voltage than that supplied to the rest of the anodes. The kathode or negative pole is common to both. This is to force the deposit into all recesses and hollows, and once this has been done by a slightly higher voltage, it will be maintained by the normal voltage.

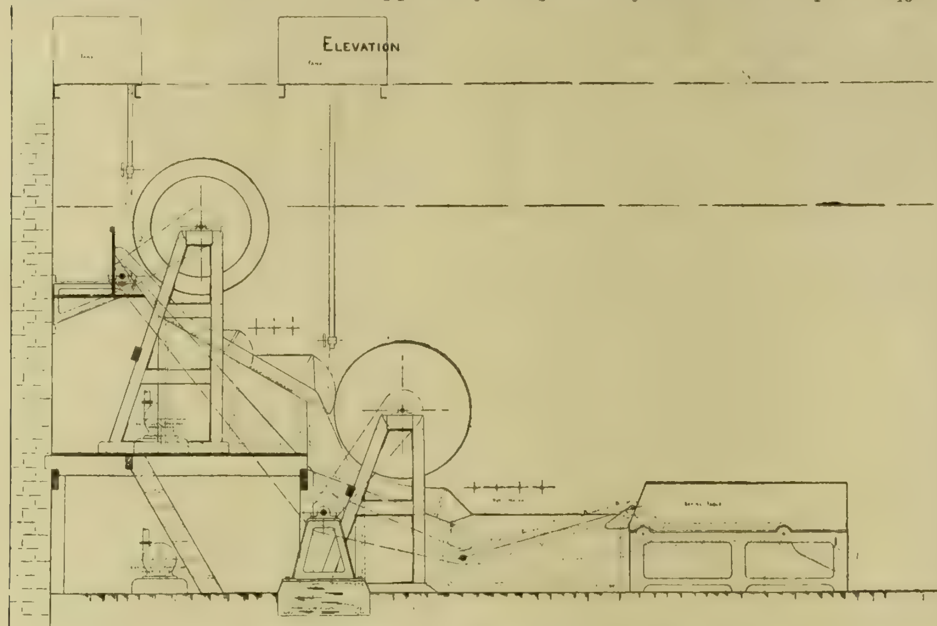


Fig. 3.—General Arrangement of Plant for Zinc Plating.

The question that will be of most interest to engineers, in any system of metal depositing, will be that of cost. It is rather difficult to state this exactly, because the amount of metal deposited will depend on the area covered and the thickness of the deposit, and area does not always bear any special relation to weight in the usual class of iron or steel goods that would require coating with another metal. But for a guide we will take the case of sheet iron coated with zinc. One ampere-hour deposits 1·2119 grammes of zinc. This is the theoretical amount and would hardly be reached in practice, but in the Marino solution, since there is no loss in decomposing the electrolyte, 1·2 grammes can be obtained. We will suppose, however, that only 1 gramme is deposited per ampere-hour and that we have to cover an area of 100 sq. ft. An ample coating for this would be 50 ozs. of zinc = 1,417 grammes.

This would require, therefore, 1,417 ampere-hours. The voltage necessary would be 2 volts. The units would be

$$\frac{1417 \times 2}{1000} = 2\cdot834 \text{ units.}$$

Taking the generator and transmission, &c., efficiency at only 50 per cent., the supply units would be 5·668. Taking current at 1d. per unit the cost would be 5·668 pence. The cost of zinc, 50 ozs. at £30 a ton = 10·044 pence. The shoots would require cleaning, and this would be very satisfactorily done by our electrolytic method. For this an area of 100 sq. ft. would require 400 amperes at 6 volts for 10 minutes

$$= \frac{400 \times 6 \times 10}{1000 \times 60} = \cdot4 \text{ unit.}$$

Again, taking 50 per cent. as the efficiency of the generator, transmission, &c., the supply units would be ·8, and at 1d. per unit would cost 8 pence.

Cost of zinc	10·044 pence.
Current for depositing	5·668 pence.
Current for cleaning	·8 pence.
	16·512 pence.

With plates $\frac{1}{16}$ in. thick a surface of 100 sq. ft. (taking both sides) would weigh about 126lbs. Take it as 1 cwt., and plates $\frac{1}{8}$ in. thick 2 cwts., &c. The cost of zinc coating sheet iron $\frac{1}{16}$ in. thick would therefore be 1s. $4\frac{1}{2}$d. per cwt. of iron, sheet iron $\frac{1}{8}$ in. thick $7\frac{1}{4}$d. per cwt., $\frac{1}{4}$ in. thick $3\frac{5}{8}$d., &c.

This is a very generous estimation because 1 ampere-hour would deposit more than 1 gramme, the generator and transmission efficiency would be more than 50 per cent.; current would be generated, and in most industrial centres bought, for less than a penny per unit, 100 sq. ft. of the various thicknesses would weigh more than the 1, 2, 3, &c., cwts. taken, and lastly a coating of 50 ozs. per 100 sq. ft. is more than is necessary. Wire and sheet iron coated by the hot system and wiped would not have anything like this coating. By the electrolytic method of course any required thickness can be put on.

The figures given, of course, only include the cost of zinc and current for cleaning and depositing. To this would have to be added labour, establishment and capital charges, &c. For work that can be handled in the revolving barrels the labour charges would be small, and the cost of power for driving the barrels should not exceed a penny per cwt. There can be no doubt, therefore, that the electro-galvanising system is very much cheaper than the hot system. This is not surprising, when we consider the sources of loss that are inherent to the old process, such as the loss due to burning the zinc, the loss for radiation, the loss from volatilisation, and the difficulty of preventing lumps and ridges solidifying before the excess of zinc can be drained off. A most important advantage of the electro system is the fact, that unlike the hot process, it has no detrimental effect on the material treated, so that steel springs can be coated without affecting their temper, and there is no loss of strength in steel chains, angle irons, girders, &c. Electro deposition by the Marino system is of course not

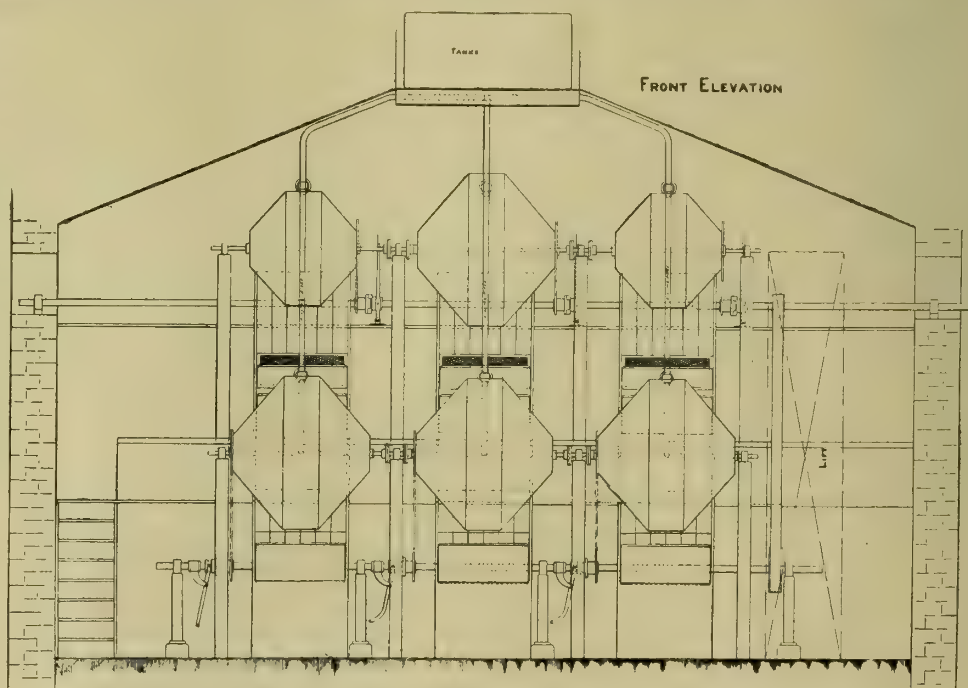


Fig. 4.—General Arrangement of Plant for Zinc Plating.

limited to depositing zinc; copper, tin, lead, aluminium, brass, and other alloys can also be deposited with equal facility.

Besides the solution for dealing with plating on to iron, Messrs. Marino have also discovered solutions for many other purposes, such as depositing metals on to aluminium, depositing alloys of silver and nickel silver and cadmium, silver and tin, &c., depositing metals on to wood, &c., and on to china and glass ware. The deposition of alloys of silver which has not hitherto been possible, such as nickel and silver, is of interest to shipowners, as they are large users of plated ware. The alloy of nickel and silver besides, of course, being much cheaper, has all the appearance of silver combined with the hard-wearing and non-tarnishable qualities of nickel. The following is a brief explanation of the process for depositing metals on to china and glass ware. The only acid that has any effect on china or glass is hydrofluoric acid H. Fl. and the chief use of this acid is for etching glass. Mr. Marino, therefore, dissolves a metal in hydrofluoric acid, usually by first reducing the metal salt to a carbonate, and applies this solution to the surface of china or glass required to be metallised. The solution then will begin to attack the china or glass carrying the metal in solution with it. By applying another metal with a higher solution pressure than the one in solution, either in the form of a powder or as a revolving brush, it will replace the first metal from its solution. The precipitated metal will therefore be firmly embedded in the pores of the china or glass and forms a foundation on which any other metal may be electrolytically deposited in the usual way.

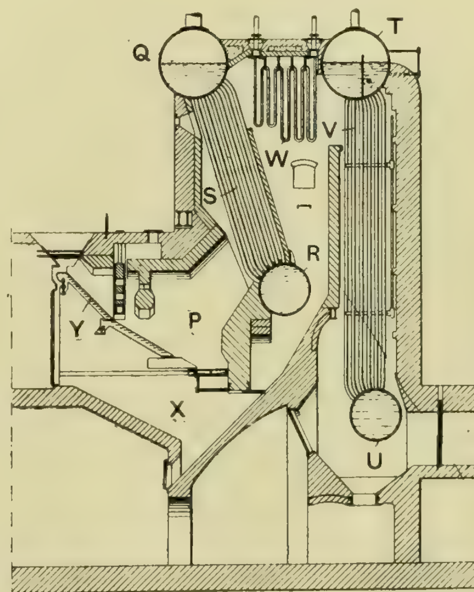
In opening the discussion, Mr. Lee pointed out that the problem of electro-deposition of metals was similar in some respects to that of corrosion, inasmuch as it was necessary to corrode one metal, the anode, to obtain the deposit on the kathode. All metals and alloys, if immersed in water—pure, or containing matter in solution—would tend to pass into solution. This tendency was due to the solution pressure of the metal and for each metal it was a constant depending on temperature for each particular solvent. The ions into which the metal was broken up carried large charges of static electricity and distributed themselves uniformly all through the solution. In endeavouring to prevent corrosion it was necessary to have some means of keeping the metal negatively charged.

The chairman, Mr. F. M. Timpson, raised the question as to whether all corrosion was more or less electrical. He understood that on certain vessels the zinc plates in the boilers had been done away with, as it was claimed that with a better circulation they were unnecessary. He had seen pipes coated with lead, which was stated to be a better protective than zinc. He understood that acid solutions were sometimes used in the cleaning of condenser tubes. Mr. John McLaren asked if the author had found it possible in practice to keep the metal negatively charged and so prevent corrosion. A system had been used to prevent corrosion in boilers by means of passing an electrical current through the water, but he did not know if it had been successfully adopted. He asked the author by what process he had been able to effect the deposition of silver on glass. Mr. W. McLaren, in alluding to the practice of putting a copper deposit on hydraulic rams, asked if such deposits were merely on the surface, or were impregnated into the metal. Plated goods, when subjected to heavy vibration or rough usage, sometimes "flaked." Plating was a species of adulteration, but if well done it was a very efficient substitute for the real metal. Mr. Jas. Adamson (hon. secretary) considered that a process of depositing on wood, if it could be done at a reasonable cost, would be a great advantage in connection with refrigerating plant. If the process could also be applied to the coating of brine pipes, it would save a great deal of the corrosion that went on in them. There was much objection to galvanising for this purpose. In the brine system also, there was corrosion at the junction of the pipes, due to a slight slackness at the screw, or to the thread being torn while being screwed. He understood this process could be applied in such a way as to seal almost hermetically the junction between the pipes and the coupling nuts.

In replying to the various questions raised, Mr. Lee said an electrical action always accompanied corrosion. In electro-depositing it was not necessary for the metal that was being deposited to combine with the other, in fact, the effect would be to weaken it. "Flaking" was due to the surface on which the metal was deposited not being efficiently cleaned, and a thin film of metallic oxide formed between the two metals. In the process with which he was associated a preparation which included borax and glycerine was used to obviate this. Lead was a good coating for pipes, as it was a very insoluble metal, but it was difficult to do the work effectively in some instances. Deposits on wood had been successfully accomplished, but not to any large extent. He did not see why the process should not be applied to brine pipes. There were many solutions that might be used for cleaning purposes, such as solutions of hydrochloric and hydrofluoric acid and sulphate of soda, but acid solutions sometimes had a harmful effect upon the metal.

STEINMÜLLER'S WATER-TUBE BOILER.

We illustrate herewith a design of water-tube boiler in which two groups of nearly vertical tubes are arranged one behind the other, each group of tubes serving to connect one or two upper drums to the corresponding lower ones, the invention of Messrs. L. & C. Steinmüller, Gummersbach, Rhineland, Germany. In such boilers it is of importance in practice to be able to replace the tubes of the element immediately adjoining the furnace, whenever required, without any difficulty and without stopping working for any length of time. To that end, it has hitherto been usual to provide either in the front wall or in the roof of the generator masonry special openings closed by doors, which enable damaged tubes to be removed and new tubes to be inserted. It is, however, difficult to keep these openings tightly closed permanently, and consequently air is liable to be unintentionally admitted to the furnace and the products of combustion are apt to escape into the boiler-house. Moreover, when such openings are provided for the repair or replacement of boiler tubes,



Steinmüller's Water-tube Boiler.

care must be taken that those parts of the walls or roof of the boiler-house opposite the openings are situated at a sufficient distance so as to provide the necessary space for the tubes to be exchanged. This leads to difficulties when space is limited.

In the design illustrated, the tubes in the front group may be exchanged without arranging any special openings and without requiring any additional room as regards the remaining available space. This is effected by considerably shortening the tubes of the front element as compared to the tubes of the element or elements situated behind to such an extent that the exchange of the front tubes can be directly effected through the furnace chamber. As a result of shortening the front group of tubes, the heating surface of this part of the generator is considerably reduced, and to compensate for this the heating surface of the rear element or elements is increased to the required degree by correspondingly lengthening their tubes. Another important advantage results from the shortening of the front element, since the surfaces with which the hottest gases come into contact—that is to say, the masonry surfaces enclosing the front element—are also reduced, and in accordance with this

reduction the losses through radiation from these surfaces are lessened, and the efficiency of the generator is increased.

Referring to the illustration, the front element directly adjoining the combustion chamber P comprises an upper drum Q, a lower drum R, and sharply-inclined or "steep" tubes S connecting the drums together. In the same way, the rear element consists of an upper drum T, a lower drum U, and "steep" tubes V. Between the two elements is arranged a superheater W. As will be seen, the tubes S of the front element are made considerably shorter than the tubes V of the element situated behind it, and their dimensions are such that they can be removed and replaced through the combustion chamber direct or through the ashpit X of the furnace. When a stepped grate Y is provided in the combustion chamber, as shown, one or more steps of the grate which subdivides the available length of the furnace chamber can be easily removed for the purpose of exchanging the tubes S.

ELECTRICAL MACHINERY IN THE TROPICS.

It is, of course, a well-known fact that the design of electrical machinery for use in the tropics requires special precautions as regards heating limits, as compared with plant for use in cooler latitudes, but it is doubtful whether in all instances the necessity for these precautions is fully realised. The following examples of the kind of trouble met with in this connection are recorded in a recent issue of the "Electrical Review and Western Electrician."

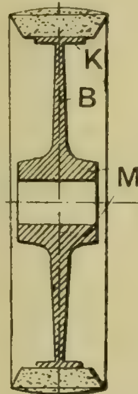
In one case in a gas-driven generating station operating in a hot climate, it was found that on one occasion the exciter on an alternator running in parallel with other machines failed, and the consequences to the supply can easily be imagined. In the particular power-house it was found that the temperature within the building averaged 104°, and it was at first suspected that something had gone wrong with the insulation of the exciter or the leads to the main generator, or that an earth had developed on the field of the generator. Tests, however, showed that the insulation appeared to be in good condition, and also there was no smell of charring or burning anywhere about the generator, and the matter appeared to be rather peculiar until the trouble was finally traced to the commutator on the exciter. It was then found that this had become so badly carbonised as to cause all the coils of the armature to be short-circuited, and such an occurrence amply explained all the rest. The commutator was cleaned by means of glass-paper at intervals of half an hour, but even this, on account of the excessive heat of the commutator due to the temperature conditions under which it was working, combined with the presence of a certain amount of gas in the atmosphere, made it impossible to prevent this fault from happening. Finally the commutator had to be taken out and turned up, and after it was replaced and given a fresh start it ran very well for a short time until the overheating again became apparent.

In the tropics, electrical discharges are very frequently met with, and this is a feature which has to be especially guarded against in the installation of electrical machinery near the equator. In spite of the great care in design which characterises the manufacture of lightning arresters, there are occasions when these do not operate with every success, and very great care should be taken in the selection of a good lightning arrester, should it be decided to install a high-tension overhead system. In one instance where a plant was constructed to generate at 5,500 volts for an overland transmission in South America, the trouble was so serious that each time a storm came on one or more of the coils in the generators were burnt out, and, in spite of all attempts to rectify the matter by the use of other types of lightning arrester, the trouble persisted and became so serious that it was finally decided to rewind the generators and motors to a voltage of 500, to install transformers to step up to 5,500 volts for the transmission line, and to step down again at the other end. In this way no further trouble was caused to the generators, the transmission system being rendered an independent link so far as electrical discharges were concerned.

Special consideration should be given in the selection of plant for tropical climates to the question of cable fittings and appurtenances, inasmuch as it will be found that in a good many types of junction box and similar gear, plant which was perfectly satisfactory for cold climates introduced a marked danger factor when used in the tropics. For example, in a large distribution box which was fed by three core cables, a lot of trouble was caused for the following reasons. The contacts for the fuses were made of pieces of $\frac{1}{16}$in. copper bent to the required shape, the grip between the fuse contact and the holders being obtained by the natural spring in these clips. This would be, of course, perfectly satisfactory under normal current-density conditions, and where a box was not subjected to external heat, but in the tropics the high atmospheric temperature, combined with a good load on the distribution system, caused an undue temperature to be maintained on the fuse clips. On one occasion a temperature of 109° was observed in the immediate vicinity of these clips, and such conditions, combined with the somewhat frequent drawing and replacing of the fuses, impaired the electric continuity and the whole box became quite warm. These fuse contacts were supported on bases which were cemented into the main structure by means of sulphur cement, and similar supports also carried the weight of the bus-bars. Owing to the local heat, together with the general temperature, the sulphur compound melted, the bus-bars became slack and started arcing, and finally the copper contacts got red hot, with serious consequences. In the particular instances noted the installation was utilised for mine-pumping purposes, and the interruption of supply caused by the giving way of this sulphur cement was a most serious matter until the pumps could be got started again. Consequently the particular junction box mentioned had to be dismembered, and the bases were mounted on plates of mica of several thicknesses to do away with the use of sulphur cement.

PULLEYS FOR HIGH-SPEED TRANSMISSION.

The employment of steam turbines has brought into prominence the question of the transmission of motion between a shaft turning several thousand times a minute and a shaft rotating at less speed. A cast-iron pulley cannot run, without failure, at high peripheral speeds, while steel pulleys are not only expensive but are also heavy. The rim ought itself to be able to resist the centrifugal force. Now, it is known that with equal length and mass, filaments composed of vegetable or animal fibres are more resisting than steel bands. A hoop, formed, for example, with glued ramie threads or filaments will resist centrifugal force better than a steel ring of the same geometrical figure and turning at the same speed. Moreover the ramie hoop will be about seven times lighter than the other.



It has been previously proposed to attach to the faces of peripheries of pulleys for machine belts one or more layers of a continuous strip or of separate strips of fibrous vegetable material, such as wood fibre, jute, linen, &c., pulped separately or together, the strips after saturation in an adhesive cement, and vulcanisation if desirable, being wrapped around the periphery of a pulley and effectually united together and to the pulley so as to form a strong and firm coating or covering to the pulley. Such a coating has been employed merely for the purpose of ensuring a firm continuous grip to prevent slipping of a driving belt or to increase the tension therein. In a patent recently granted to Messrs. Westinghouse-Leblanc, 45, Rue de Berlin, Paris, it is proposed to form the felloe of the pulley by winding around a thin rim plate several folds or layers of a strip or band consisting of animal or vegetable filaments impregnated with an agglutinant such as vulcanised caoutchouc, gelatine or artificial cellulose as cellit, viscose, &c., to form a bobbin which is made of such dimensions that it alone, without the aid of the rim plate, will be sufficiently strong to resist the stresses due to centrifugal force, the rim plate serving merely as a base member on which to wind the filament band and which, if the construction so allow, may be removed after the felloe is formed without affecting the strength of the pulley. The pulley illustrated has a steel nave M and arms B supporting a rim K of thin plate. The pulley being mounted on a shaft, there is wrapped around the rim a long continuous filament of ramie, cotton, flax, hemp,

silk, camel hair, or other suitable substance, in regular and successive layers which are successively impregnated with an agglutinant, each fresh layer being left to dry if the agglutinant is applied in solution, *e.g.*, gelatine, or artificial cellulose, or the entire pulley is placed in a vulcanising furnace if caoutchouc is used. The tension with which the filament is wound will be determined exactly, and will change from one layer to another so that it will always at least be equal to that resulting from centrifugal force during rotation. Any form can be given to the rim, cylindrical or arched, with one or more grooves, &c. It can be of any size and be such as to constitute a drum. The body of the pulley and the light rim serving to support the bobbin can be formed in any desired manner. It may be of paper or compressed pasteboard, protected or reinforced with vegetable or animal fibres. In the case where the rim support does not afford an effective connection in the direction transverse to the several spiral layers circular bands may be disposed between consecutive layers, forming a cylinder around the pulley which bands may be formed of filaments of vegetable or animal fibres agglutinated together.

INDUSTRIAL AND TRADE NOTES.

Orders for Cruisers.—Orders for two light armoured cruisers have, we understand, been provisionally placed by the Admiralty with Messrs. Vickers, Ltd., Barrow-in-Furness, and two similar vessels with Messrs. W. Beardmore & Co., Ltd., Dalmuir.

South Wales Miners and the Federation.—The anthracite district of the South Wales Miners' Federation, which has a membership of nearly 18,000, and is the largest district in the Federation, decided on Saturday last, at a meeting held in Swansea, to break away from the Federation and conduct its own affairs.

Hematite Iron.—On Monday last hematite iron was quoted at 85s. per ton. This is a record price for about a dozen years, for in 1900 there was a price quoted of 86s. 10d. per ton. It compares with 55s. per ton for the same class of iron in the year 1909, and with 51s. 9d. in the year 1904. These fluctuations in price are to some extent caused by the activity or inactivity in the shipbuilding industry.

The New Thames Tunnel.—Within a few weeks the new tunnel under the Thames connecting north and south Woolwich will be opened for traffic. Operations have been in progress over two years, and the cost of the scheme is about £80,000. Hitherto the only means of crossing the river at this point has been by a free ferry. This will be the fourth tunnel constructed by the London County Council.

Clyde Shipbuilding Activity.—With the biggest September output on record, the total tonnage launched from the Clyde yards for the nine months of the year is also brought up to a record, and there is some likelihood now of the year's total being larger than ever before in the history of the industry. The output for the month consisted of 20 vessels, aggregating 53,894 tons, and the tonnage for the nine months amounted to 471,744 tons, which is about 11,000 tons over the previous best total for the period.

New Destroyer Depôt Ship.—The London and Glasgow Engineering and Iron Shipbuilding Company (Messrs. Harland & Wolff), launched on the 25th ult., from their Middleton Shipyard, Govan, the twin screw steamer "Woolwich," which they have built as a depôt ship for torpedo boat destroyers for His Majesty's Navy. The vessel is 320ft. in length between perpendiculars, 40ft. in breadth, and 21ft. in depth. She will be fitted with twin screw reciprocating engines, and will have a very large and complete outfit of machine tools of practically all descriptions.

Wages in the Iron Trade.—On Saturday last the Midland Iron and Steel Wages Board, which regulates wages in Staffordshire, Lancashire, Yorkshire, and Wales, declared an advance of 2½ per cent. The average selling price of iron for the past two months is declared at £7. 10s. 3¾d. and the output 41,200 tons, against £7. 4s. 9d., and 43,500 tons in May and June. The Scottish Manufactured Iron Trade Conciliation and Arbitration Board also declared an advance of 2½ per cent. The average net selling price of iron for the past two months is declared at £6. 17s. 3·47d. per ton. In the North of England the wages of ironworkers will remain the same as in the previous two months.

Motor Boats in China.—It is interesting to learn, says "The Motor Ship and Motor Boat," that nearly all the motor-boats in service in Chinese waters are fitted with British oil engines, a large number being Thornycroft and Gardner. The field for the sale of motors in this part of the world is rapidly opening out, and firms in this country might do well to pay even greater attention to Eastern trade than they have hitherto done. Business, particularly in China, is generally good, and there are many opportunities for the employment of motor craft, both for commercial and pleasure purposes.

Trades and Railway Agreements.—The alleged arbitrary action of the railway companies serving Birmingham and district has led the Chamber of Commerce to issue an appeal for £1,000 to protect traders. It states that it is intended to retain a railway expert for the assistance of contributors in cases of dispute, to retain a qualified adviser, and to arrange for the conduct of test cases involving traders. It is pointed out that the closer co-operation between railway companies and the agreements and working arrangements entered into between them have effectually eliminated competition, and that a trader is unable to obtain the same fair and equitable treatment as when there was competition between the companies.

Palmer's Shipbuilding and Iron Company.—Lord Furness, in his letter of resignation of the chairmanship received at the annual general meeting at Newcastle, of Palmer's Shipbuilding Company, Jarrow, said he confessed to a feeling of disappointment at the meagre response by the shareholders to the appeal he made for capital to carry out the policy adopted and recommended by the board for extensions and the consolidation of the whole concern. Although he would no longer have any active participation in the affairs of the company he retained his holding as a shareholder so that his interest in its welfare would not diminish. The balance sheet showed a deficit of £31,500, and the total debit balance was £128,113. The coal strike cost the company £30,000.

New Clyde-built Oil Motor Ship.—The new single screw motor vessel "Fordonian," which has been built by the Clyde Shipbuilding and Engineering Company, Port Glasgow, for service on the Canadian Lakes, recently completed her trials, with satisfactory results, and will shortly leave Glasgow for Sydney, Cape Breton. The vessel, which is 250ft. in length, is of about 2,000 tons gross, and has a carrying capacity of 2,800 tons. She has been supplied with engines of the Carels Diesel type by the builders, who are licensees for Messrs. Carels Frères, Ghent. The machinery of the "Fordonian" is of the four-cylinder 2-stroke type, driving one shaft, and it is capable of developing power equivalent in a steam engine to 950 i.h.p.

Orders for Diesel Engines.—Messrs. Willans & Robinson, Ltd., of Rugby, have recently obtained orders for a 1,600 h.p. Diesel engine for the Midland Construction Company of Oshawa, Canada, and two similar engines required by Messrs. Dick, Kerr, & Co., Ltd., for the Prince Rupert Hydro-Electric Company of Vancouver. They are also executing an order from Messrs. Strain and Robertson for two engines of this type required for the La Patria Nitrate Company, of Chile, and they are completing an installation of a 200 h.p. engine for the Rugby Urban District Council Waterworks, where it will be used to drive a high-lift turbo pump. A 50 h.p. engine ordered by the London and North-Western Railway Company for pump driving is also in hand.

Launch of a "Combination" Steamer.—Messrs. William Denny and Brothers, Dumbarton, launched on Saturday last the "combination" triple screw steamer "Infanta Isabel de Borbon," which they have built for the Compania Transatlantica, Barcelona. The vessel has been designed for passenger trade between the South of Europe and South America. She is 480ft. in length between perpendiculars, 61ft. in breadth moulded, and 35ft. 9in. in depth moulded. The propelling machinery will consist of two sets of triple expansion engines and an exhaust turbine, a combination first adopted on the "Otaki," built by Messrs. Denny in 1908, and followed since with success in a number of large steamers. The whole of the propelling machinery is being made by Messrs. Denny and Co.

Trans-Australian Railway.—The Trans-Australian Railway connecting Western Australia with the Eastern States of the Commonwealth, of which the first sod was turned by the Prime Minister at Port Augusta recently, is to be supplemented by a railway from Fremantle to Kalgoorlie, duplicating the existing railway. This new line, which will be over 380 miles in length, is to be built by the State Government, who have just introduced a Bill into the Legislative Assembly providing for the construction of its largest section, from Merredin to Coolgardie, at a cost of £676,081. The State Government are entering upon this project early in order to expedite the work of building the Trans-Australian main line. The contract for the supply of the 80lb. rails to be used has been placed with a British firm.

Iron and Steel Industry in Italy.—During 1911 the imports of crude iron and steel into Italy amounted to 191,752 tons, as against 284,432 tons in 1910. Manufactures of iron and steel, and of other metals, were imported to the value of £22,600,000, an increase of £800,000, while the exports reached a total of £3,200,000, an increase of £400,000. The most important events

in the metallurgical industry were the combination formed by the Societa Savona, Piombino, Elba, Ferriare Italiane, Ilva, and Metallurgica di Sestri, and the strike in the Elba iron mines, which lasted nearly five months and caused the imports of iron ore to rise from 17,673 tons in 1910 to 50,553 tons in 1911. During the latter year 232,811 tons of pig iron and 392,703 tons of "scrap" were imported.

German Technical Schools for China.—At a recent meeting of the Wakefield Incorporated Chamber of Commerce and Shipping, Mr. G. E. Tennant, the president, called attention to the fact that the German Government had decided to build four technical schools in China for the purpose of teaching Chinese students engineering in all its branches. German firms had been approached with a view to their making gifts towards the fitting up of the buildings, and the German company in connection with his firm had given one of their fuel economisers. He had written to the English Government, pointing out what had been done, and suggesting that the ultimate object was to secure the Chinese market for German firms, and he had received a communication from the Foreign Office expressing the thanks of Sir Edward Grey for the information.

High-speed Wireless Telegraphy.—On Monday last Marconi's Wireless Telegraph Company gave a demonstration of high-speed automatic transmission at their works at Chelmsford, to the representatives of the British Post Office, the Admiralty, the War Office, the Colonial Office, and Crown Agents. The high-speed signals transmitted from Poldhu, Cornwall, where other representatives of the Government were present, were received and recorded at Chelmsford, both by means of a recorder, on the principle of a gramophone, and printed on tape. It was demonstrated that by these means signals could be received at a high rate of speed on a recording cylinder, the cylinder being afterwards caused to repeat the messages at a rate of speed sufficiently low to enable the operators to read them. With the other method a printed tape left the receiver recording the messages as they were received.

The Canadian Rail Industry.—The present annual output of Canadian rail mills reaches 400,000 tons, which is sufficient to lay 3,000 miles of line. Railway construction this year, however, has been so active that heavy imports of steel rails from the United States have been rendered necessary, the above output representing only 90 per cent. of the total consumption. The necessity of these imports is not due to the inability of the Canadian mills to supply the total requirements, for their capacity is fully 50 per cent. greater. It is due to the lack of foresight of the railways themselves in estimating accurately their requirements in advance, and to the conditions that surround the manufacture of rails. The Canadian steel companies make contracts each autumn for the whole of the next rail season's needs, and then arrange contracts for the balance of their steel output for other lines of manufacture. The unforeseen demand in the circumstances, therefore, had this year to be obtained from abroad.

Markets for Oil Engines.—H.M. Consul at Casablanca in a recent report states that in connection with the farming industry in Morocco heavy oil motors are much more suitable than steam generators. Petroleum is cheap, while coal is expensive. Mechanical traction with heavy petroleum oil motors is considered, therefore, the most suitable. The British Vice-Consul at Omsk states that the demand for oil engines is steadily increasing in Siberia, the majority in the Omsk district being of Swedish origin, although those of British and German manufacture have a share of the trade; lately, Russian engines have made a name and are likely in the future to take a leading position, as not only is the article a good one, but the price is competitive; British firms wishing to retain a share of this business would do well to watch developments, as competition is very keen. A large number of small flour mills are being built throughout the country. The largest mills are worked by steam, but the majority of the smaller ones are run by oil engines.

Improving the Port of London.—The Port of London Authority have now accepted tenders amounting to £2,350,000 for dock extension and improvements, covering the more important works immediately contemplated, which form the first portion of an extensive scheme involving a total expenditure of over £14,000,000. The work now placed with Messrs. S. Pearson & Sons, Ltd., comprises the Albert Dock (South) extension, and improvements at the East and West India, London, and Tilbury Docks. The South Albert Dock will possess a water area of 65 acres and a depth of 35ft., capable of being increased to 38ft. The plans also provide for a dry dock 650ft. long, increasing when necessary to 800ft., and with a width of 100ft. Pending its construction the existing Western Dry Dock at the Albert Dock will be enlarged. A large steel swing bridge will connect the new South Albert Dock, which is expected to be completed within four years, with the Albert Dock. Other features, bringing the port up to modern requirements, include extensive widening and deepening operations, and the provision of new jetties, transit sheds, and other equipment.

An Extensive Waterworks Filtration Scheme.—Situated between the Wessenden Valley Reservoirs of the Huddersfield Corporation and the Woodhead Reservoirs of the Manchester Corporation is the watershed of the Ashton, Stalybridge, Mossley, and Dukinfield Joint Waterworks Board. In the valleys at Greenfield, Chew, and Swineshaw are seven or eight huge reservoirs, which supply water to a population of 140,000 people, distributed over an area of 52 square miles. For some years past complaints of lead poisoning were prevalent in the Yorkshire part of the Board's area, and to remedy this the Board decided to undertake a scheme of filtration. This work has been carried out, at a cost of £30,000, and on Thursday, September 19th, the filtration stations at Greenfield, Saddleworth, and Swineshaw—amongst the largest of their type in the kingdom—were officially opened. The two installations comprise 36 pressure filters, designed to purify collectively 5,352,000 gallons of water per day. The filters and the chemical plant have been supplied and erected by Messrs. Mather & Platt, Ltd., of Manchester. Practically the whole of the power in the filter houses is generated by water.

Trade Unions and Overtime.—A central conference between the Engineering Employers' Federation and delegates of the Amalgamated Society of Engineers, the Steam Engine Makers' Society, and the United Machine Makers' Society was held on the 28th ult., at York, to consider several questions that had not been settled in local conferences. Sir Benjamin Browne presided. The main question came from Hull, and it had to do with the meaning and scope of the words "urgency" and "emergency" in relation to overtime working. The agreed limit of the amount of overtime which may be worked is 32 hours in any four weeks, but there is a proviso in the existing agreement that in cases of "urgency and emergency" more hours may be worked. The Hull society claimed that the employers had abused this privilege, that they had called upon the men to work as much as 42 and 50 hours in the period named, and the A.S.E., in pursuing their policy of limiting overtime as much as possible wished for a definition of the words "urgency" and "emergency." On this question we understand that a settlement was arrived at. In any case no alteration to the wording of the overtime rule was made. Assurances, it is stated, were given from the employers' side that no undue overtime was worked, that if any extra hours were put in, it was due to extraordinary pressure and urgency, and the whole matter, after an amicable discussion, was referred back to the parties concerned at Hull.

The Shrewsbury Mono-rail.—A demonstration was recently given at Chadwell Heath of a new system for the transportation of timber, stone, and other heavy articles, by the Shrewsbury Portable Mono-rail Syndicate, of which Mr. T. W. How, of 17, Victoria Street, S.W., is the consulting engineer. The experimental track at Chadwell Heath is one-eight of a mile in length. It is designed to carry four tons, is constructed with a 19½lbs. rail mounted on timber placed longitudinally and supported on vertical posts at a height of 5ft. 6in. above the ground. The truck consists of a light steel framework, about 15ft. long, carried on four wheels, of which two are placed at each end, one behind the other, each pair being fitted in a bogie frame. From cross-arms on the truck are suspended two cradles, one on each side of the track, reaching to within a few inches of the ground, on which the loads are placed. An efficient system of braking is provided for which it is claimed that down gradients so steep as 1 in 5 can be negotiated safely. The principal claim for the system is that it provides a means of transport at moderate speeds in places where an ordinary railway would be too expensive. The cost of construction with timber trestles is put at £600 per mile. The tractive power is provided by horses, but it is suggested that a petrol motor could be provided if desired.

Amalgamated Society of Engineers' New Rules.—In a preface to the minutes of the Amalgamated Society of Engineers' recent delegate meeting at Manchester, the principal alterations which were made in the rules are indicated. According to these the qualification for membership of the society has been considerably relaxed, practically all the metal workers being now eligible. The entrance fees for full members are reduced, and apprentices are to be admitted without any entrance fees. The rules relating to contingent benefit make changes which will materially increase the cost of it. It is to be paid to members who refuse to work with men belonging to other trades who have been introduced to do the work of strikers. It will also be paid to members who are thrown out of employment through a "general" strike in another industry. The Executive Council disagrees with the delegates regarding the abolition of the machinist section, and is taking the opinion of members upon the question. In its final form the rule relating to the terms of agreement and the premium bonus

system reads as follows: "The Executive Council shall within three months of these rules coming into force take the votes of the members in favour of giving the Engineering Employers' Federation three months' notice to end the 'terms of agreement, 1907,' also the 'memorandum *re* premium bonus system.' If a majority are in favour of ending them three months' notice shall be given by the Executive Council to the Federation at once."

The Ghent International Exhibition.—One of the striking features at the British section in the Ghent Exhibition in April next year will be the display of British tools made by British manufacturers. A large number of the firms who are exhibiting at Olympia have, we understand, taken space, and there is every indication of this section of British industry being well represented. It will afford British tool-makers an opportunity of placing before continental buyers an adequate idea of the pre-eminence in excellence of their tools for every purpose. Belgium itself, with its low tariff, furnishes an excellent market, and the neighbouring countries of Holland and Denmark are valuable customers. Apart from these, the opportunity of doing business with Russian, Austrian, Italian, and other foreign buyers is an excellent one. The exhibition will be a large one, and the site chosen for it is in a central and accessible position on the main line of railway from Ostend to Brussels. The exhibition as a whole is under the patronage of the Belgian Government. There are excellent prospects for a great success being achieved, the more so as no important international exhibition is likely to be held again in Belgium for many years. The British section, which is being organised officially by the Exhibitions Branch of the Board of Trade, will be devoted mainly to machinery. Little time now remains before the list of exhibitors will be closed, and British firms desirous of availing themselves of the opportunity offered to take part in this exhibition should lose no time in communicating with the Exhibitions Branch of the Board of Trade, Queen Anne's Chambers, Westminster, London, S.W., which department is responsible for all arrangements.

Lining Mine Shafts with Ferro-concrete Slabs. — In place of the usual brick lining segmental slabs of concrete reinforced with expanded steel have been used for two new shafts at the Plenmeller Collieries, Haltwhistle, Northumberland, by Mr. T. Blandford, the engineer to the colliery. The slabs were made of a size (3ft. 1in. by 1ft. 6in.) convenient for handling, and, after being allowed to season, were lowered into the shaft and fixed in position. They are 5in. in thickness, and are reinforced near their concave face with expanded steel, which has a cross-sectional area of ·25 of a square inch per foot of width short-way of mesh. The slabs are tongued and grooved on edges to allow of their fitting and keying into each other, the joints being filled with cement grout to make the segments a monolithic cylinder when placed in position. A hole was left in each slab—about 1in. in diameter on the concave face, and slightly larger on the convex face—to allow of their being slung and lowered into position, as well as to serve as an inlet for cement grout to be injected into the concrete filling behind them after the slabs had been fixed in position. The lining of the shafts was completed through water bearing strata which had been previously treated by the François method of cementation, and the cavity between the reinforced concrete lining and the face of the strata, left in the process of sinking the shafts, was filled with ordinary concrete to a thickness of 9in. behind the lining during the course of the ring of the lining; this concrete being finally filled up solid by injection through the lining with cement grout, thus making it watertight.

The Effect of Strikes.— At the recent annual meeting of Bolckow, Vaughan, & Co., Ltd., the chairman said the gross profit for the year, after allowing for depreciation, was £209,891, compared with £286,599 the year before and £286,135 two years ago. This diminution was wholly due to the coal strike of last spring and the railway strike in August of the previous year. Had it not been for the coal strike, he had no hesitation in saying that their profits for the year would have shown a substantial advance on the year before. He was aware, he said, that the result of the year's work was disappointing. Their production of iron-stone during the year had been 1,583,615 tons, as compared with 2,078,185 tons the year before. Their production of coal had fallen from 2,343,100 tons in 1911 to 2,078,924 tons in 1912. The production of coke had been 575,028 tons, as compared with 743,849 tons in the preceding year, and their production of limestone 156,538 tons, as compared with 183,575 tons the previous year. In August last year the whole of their works were stopped for a week owing to the railway strike, and it was quite one month before the blast furnaces recovered from the effect of the stoppage. The total loss to the company from the railway and coal strikes was between £107,000 and £108,000. During the year they had had at each of the collieries or coke ovens eight other minor strikes, all of which caused serious loss and dislocation of their plant, and by which the men themselves gained nothing. As a result of a strike they had permanently closed and dismantled the Brusselton works. This had thrown a considerable number of men out of employment. The chairman added that the Insurance Act involved the company in the sum of between £13,000 and £14,000 a year. As to the future, orders were likely to be plentiful, and with an absence of labour troubles and higher prices, they might look forward to a satisfactory year.

World's Petroleum Production.—The following table, compiled by the United States Geological Survey, gives the world's production of crude petroleum for the years 1910 and 1911. According to this, the total production last year was over 345½ million barrels, as compared with nearly 327½ millions in 1910. Of this total the United States contributed 63·80 per cent., Russia 19·16 per cent., Mexico 4·07 per cent., and the other countries in the order given in the table. No other country is likely to produce more than 4 per cent. of the total supply, which probably will not increase beyond the present total.

World's Production of Crude Petroleum in 1910 *and* 1911.

Country.	1910.	1911.		
		Barrels.	Metric tons.	Per Cent. of Total Production.
United States ...	209,557,248	220,449,391	29,393,252	63·80
Russia............	70,336,574	66,183,691	9,066,259	19·16
Mexico	3,332,807	14,051,643	1,873,552	4·07
Dutch East Indies	11,030,620	12,172,949	1,670,668	3·52
Roumania	9,723,806	11,101,878	1,544,072	3·21
Galicia	12,673,688	10,485,726	1,458,275	3·04
India	6,137,990	6,451,203	897,184	1·87
Japan	1,930,661	1,658,903	221,187	0·48
Peru	1,330,105	1,398,036	186,405	0·40
Germany	1,032,522	995,764	140,000	0·29
Canada	315,895	291,096	38,813	0·08
Italy	42,388	71,905	10,000	0·02
Other	30,000	200,000	26,667	0·06
Total	327,474,304	345,512,185	46,526,334	100·00

Copper Alloy Rails. —It is reported that the Chicago, Milwaukee, and St. Paul Railway will make a test of steel rails containing about six-tenths of 1 per cent. of copper. A trial order has been placed with the United States Steel Corporation and a thorough experiment will be made with the rails along the St. Paul lines. These rails, which are no more expensive than the ordinary steel rails, will, it is thought, withstand the wear and tear of hard usage better than the rails now in general use.

Wilbur Wright Monument.—The Aero Club of France has opened subscriptions for a monument to the memory of Wilbur Wright, to whom, in conjunction with his brother, Orville Wright, is allowed the distinction of having been the first of the flying men. It is proposed to erect the monument at Auvours, which was the scene of Wilbur Wright's memorable demonstrations of flight in France. It is also intended to present the aeroplane with which he achieved some of his most famous records to the Conservatoire of Arts and Trades.

Defective Goods Train Couplings.— In his report, issued a few days ago, concerning a collision on the L. and N. W. Railway at Hest Bank Station, on July 22nd last, which was due to the breaking of a coupling, Col. Yorke states that a great number of failures of couplings are reported to the Board of Trade every year. He says that last year the number of failures of couplings reported to the Board was 2,934, and probably there were many more of which nothing was heard. Of the number reported 2,270 occurred on goods trains, and an analysis of the returns showed that 1,777 were cases of actual fracture, while the remainder were due to the couplings becoming detached through jumping off the draw hooks. Although, fortunately, such failures did not often cause accidents to passenger trains, owing to men being more on the alert than in the case of the accident at Hest Bank, each of them, the Inspector remarks, was a potential cause of disaster, and they did, as a fact, frequently result in injuries to men, damage to goods trains, and delays to and dislocation of traffic. He, therefore, thought it would be well for the railway companies to look into the strength and design of the couplings in general use on goods trains. The existing three-link coupling was, as far as he knew, only used in Great Britain, and even if a little more money were spent on it, it would still be the cheapest coupling in the world.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Valves for use in gas-manufacturing apparatus. Clapham. 11355.
Change-speed gear. Austin Motor Company, and Austin. 11573.
Working of gas producers. Chadwick & Hollinshead. 16168.
Carburetters for internal-combustion engines. Berwick & De Beer. 19739.
Apparatus for producing gas for driving, heating, and other purposes. Hendunen & Simonenko. 19781.
Internal combustion engines. Frith. 19813.
Arbors for milling cutters. Brewinski. 19864.
Oil burners. Mason & Donnelly. 19963.
Two stroke-cycle internal combustion engines. Cloudsley. 20025.
Valve mechanism of internal-combustion engines. Lindblom. 20050.
Valves. Havers. 20114.
Process and furnace for melting ferro-manganese and other ferro-alloys. Bronn. 20121.
Liquid-fuel sprayers. Wolff. 20122.
Means for use in promoting ventilation in subterranean mines. Mavor & Coulson, Ltd., and Mavor. 20188.
Treatment or renovation of foundry sand. Poulson and Poulson's Foundry Specialities, Ltd. 20204.
Appliances to prevent overwinding with winding or hoisting engines. Bever. 20226.
Internal-combustion engines. Roots. 20256.
Luffing cranes. Mitchell. 20267.
Means for locking nuts on bolts. Guest. 20277.
Fuel blocks or briquettes. Hoering. 20312.
Internal combustion engines. Lines & Lines. 20390 and 20393.
Automatic speed-control of motors. Belliss & Morcom, Ltd., and Walshe. 20547.
Internal-combustion engines. Hutchinson. 20615.
Spanners and wrenches. Roots. 21448.
Cylinders of internal-combustion engines. Tanner. 22155.
Speed indicating and recording apparatus. Baumrucker & Schuch. 22980.
Rock drills. Rayner. 23103.
Furnaces. Johnson. 23431.
Clutch and reversing gear for marine, motor, and other shafts. Langdon & Kellaway. 24324.
Hydro-aeroplanes. Wakefield. 27770.
Unions or couplings for cocks. Stephens. 28040.
Silencers for internal-combustion engines. Houghton. 28392.
Turret lathes. Herbert & Vernon. 28442.
Gas burners for working metals. Continental-Licht-und Apparatebau-Ges. 28700.
Steam supply valve with pendulum governor for ships' engines. Brouquière. 29276.

1912.

Machines for butt-welding metallic tubes. Sangster. 215.
Guard for circular saws. Brookes. 738.
Control mechanism for the cage-lifting devices of mining apparatus. Mansfeld'sche Kupferschiefer Bauende Gewerkschaft. 1167.
Pipe joints. Ames. 2786 and 2832.
Geared die stocks for screwing tubes, drilling and boring. Mansfield. 3414.
Aerial propellers. Olmsted. 3498.
Fuel economiser. Mulby. 4338.
Double acting tandem compound engines with stage piston. Jung. 4678.
Rotary engines. Conill. 4911.
Lock nuts or washers. Norris. 5351.
Means for uniting the ends of sheet-metal tubes. Hall & Kay, Ltd., Hall, & Kay. 5507.
Self-lubricating bearing. Westley. 5835.
Machines for slotting screws. Monks. 6637.
Nut locks. Garchey. 7162.
Starting devices for motor-cars. Heyl, and Ges. fur Automobil-Renovierungen. 9192.
Friction driving mechanism for motor vehicles. Owen. 10131.
Motor road vehicles. Jofeh & Moody. 10318.
Aeroplanes. Clément. 10358. (May 2nd, 1911.)
Balanced cylindrical slide valves for motor fluid engines. Soc. Anon. dite Etab. Piguet Constructions Mecaniques and Gruffe. 10456.
Device for purifying the steam in steam generators. Luhn. 10577.
Pipe couplings. Mitchell & Hamer. 10788.
Rock drills. Rayner. 13657.
Ignition devices for internal-combustion engines. Ott, Fanta, and Ott. 13688.
Clutches. Lanning. 13798.
Regenerative gas-generating furnace with constant direction of the heating flames. Stettiner Chamotte-Fabrik Akt.-Ges. vorm. Didier. 14702.
Drop feed lubricators. Stern Sonneborn Oil Company. 14913.
Guards for power presses. Veritys, Ltd., and Rogers. 14998.
Joints for transmitting fluids between stationary and rotating bodies. Prather. 15257.
Apparatus for producing gas for driving, heating, and other purposes. Hendunen & Simonenko. 19515.

ELECTRICAL, 1911.

Electrical terminals and fuses. Anness. 17593.
Transmitting apparatus for wireless telegraphy. Rouzet. 19948.
Electrically-operated boat hoists. Fielding. 20383.
Telegraphic relays. Brown. 20451.
Production of copper by electrolysis. Douvreleur. 21593.
Sparking plugs. Fletcher. 24941.
Devices for operating tramway points or switches from the vehicles. Weiczner & Laczay. 28565.
Arc lamps. Tate. 29035.

1912.

Feeding mechanism for the electrodes of arc lamps. Steinert. 1755.
Method of multiple control for electric motors. Richter and Maffei-Schwartzkopff-Werke Ges. 3117.
Speed-regulating devices for electric motors. Jacquet Freres. 4691.
Telephone exchange circuits. Siemens Bros. & Co. 4698.
Instrument for measuring frequencies, self-induction co-efficients and capacities, and ratios of self-induction co-efficients and capacities. Thompson. 7657.
Electro-deposition of metals. Leuchter. 9075.
Electric measuring instruments. Hubert. 9411.
Combined telephonic transmitters and receivers. Thompson. 12545.
Selector for automatic or semi-automatic telephone systems. Siemens Bros. & Co. 18430.

METAL QUOTATIONS.

TUESDAY, OCTOBER 1st.

Aluminium ingot	82/- per cwt.
" wire, according to sizes, &c. ......from	102/- "
" sheets " " ...... "	120/- "
Antimony ......£34/-/- to	£36/-/- per ton.
Brass, rolled	9¾d. per lb.
" tubes (brazed)	11¾d.
" " (solid drawn)	10d.
" " wire	9½d.
Copper, Standard	£78/15/- per ton.
Iron, Cleveland	67/- "
" Scotch	73/- "
Lead, English	£22/-/- "
" Foreign (soft)	£21/5/- "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£8/-/- per bottle
Silver	29½d. per oz.
Spelter	£27/7/6 per ton.
Tin, block	£228/10/- "
Tin plates	15/4½ "
Zinc sheets (Silesian)	£31/2/6 "
" (Stettin; Vieille Montagne)	£31/-/- "

The Ditton Railway Disaster.—At the resumed inquest on 14 of the passengers who lost their lives in the disaster to the Welsh express at Ditton Junction on the 17th ult., a verdict was returned to the effect that the derailment was due to the train being driven at excessive speed.

New Navy Airship.—The new airship "City of Cardiff" is now practically ready for flight at the aircraft factory at Farnborough. The airship, which is slightly smaller than the "Beta," will carry four passengers, and will be used, according to present arrangements, only for naval reconnaissance.



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The Town Transport Situation.

THERE is no more important problem confronting the engineering profession—and the pressure is not confined merely to that section calling themselves tramway engineers—to-day than that presented by the transport situation in our large towns. It is not merely a question of carrying capacity, as it appeared to be, say, 10 years ago. It is more than that. The coming of the high-speed electric tramcar was such an improvement on the old horse car that for a few years, with the exception of London, the only serious problem was the suburban steam railway, which found itself robbed of no small part of its traffic. The London exception did not trouble non-Londoners, because it appeared as if the London problem was mainly explained by the comparative absence of electric trams in London and the continued existence of the uncomfortable, slow-moving, and low-capacity horse 'bus. To-day the situation is changed, and London dominates it. During recent years the motor 'bus has found itself. This is especially true of London, and the last financial year witnessed a decrease in the tramway traffic of the London County Council, but a very marked increase in the traffic secured by the motor 'buses. This fact has been discussed by the London daily Press and by the technical Press, and in general welcomed joyfully as an indication that the tramway is about to succumb before the onslaught of the motor 'bus. At the West Ham Conference of the Municipal Tramways Association the London situation came up for discussion, and it is evident from expressions of opinion there and elsewhere that there is a large body of interested opinion which believes the usefulness of the electric tram to be past its zenith. Although many of these opinions are expressions of political faith rather than technical argument, it would be unwise to dismiss the present extremely difficult town-transport situation as devoid of engineering interest.

It is desirable first to point out that, although not without lessons of general application, the London situation is distinctly special at the present moment. It is special because

most towns have no motor 'buses to trouble them at present and because the London streets, with their comparatively smooth road surfaces, are relatively more favourable to the 'bus than the stone sett pavements usual in most large towns. Further, to a large extent the London struggle is for local or short journey traffic, whereas the tramways of most towns depend to a much larger extent upon the traffic between home and business. It is one of the grounds of complaint of the 'bus supporters that the trams are encouraging people to live too far out from business, and the success of the 'bus is partly to be measured by its ability to hinder this outward movement by offering cheap facilities to those who remain. Then, too, the tramcar begins to be at a disadvantage in a congested street, and London has far more of these than any other town. A tramcar is tied to the rails and is in itself a serious obstacle to other traffic. Further, its passengers in passing to and fro between the car and footpath are also a hindrance to the vehicular traffic, as every town can demonstrate. The motor 'bus is not tied to rails and does get through dense traffic more readily than the tram. As regards its passengers there is also an advantage when, as is usual, these are received or discharged at the edge of the footpath. Under present conditions, then, in a congested street the 'bus seems to possess the advantage, and for local traffic there is a good deal of justification for this point of view.

There are, however, other factors to be taken into consideration. For the home-and-office traffic the demand for accommodation is beyond the 'bus, except when the distance is small. Even the present trams are too small and a 'bus the size of the large two-bogie, double-decked tram is hardly practical. The London County Council are making the mistake of seeking powers to run trailers, which would increase the obstruction of the traffic, reduce the speed of the cars, and have other disadvantages, offset only by that of greater carrying capacity. Also, the 'bus is, except on the best pavements, a very inferior vehicle to travel in. In London the pavements are of the best, but even there the jolting is not to be laughed at, and the swerving is worse. Single-truck trams are about the limit of barbarism which ought to be permitted in a public conveyance, and any form of 'bus at present in existence is well outside the limits for all except perfect road surfaces and a thin traffic, which eliminates the necessity for following a cork-screw path. One may, of course, tolerate a barbaric method of travel for short distances, and it may be that the motor 'bus, by reason of its convenience and speed in business centres, is destined to establish itself for localised services in large towns.

The localised services of our large towns do not, however, touch the main problem of the town-transport situation. That problem is mainly that of carrying between home and business. There is not a tramway system in any of our large towns which has solved this problem, although its solution is as pressing as that of the supply of drinking water to the inhabitants. The railways are equally far from solving the problem, with the result that the central districts are steadily becoming more and more congested and the utility of the trams less and less. The remedy will not be found until the British conception of a tram is fundamentally altered. A man riding three or four miles from his home to the office does not want to stop every two or three hundred yards and, what is more important, he cannot afford to stop. Nor does it pay the tramway system to stop a full car for an odd passenger at an intermediate point. Intermediate passengers must be catered for separately. In fact, the tramway system must approximate to that of the railway in this respect, that there must be express cars and intermediates and that the average schedule speed must be very much increased. On the other hand, the frequency of service must be maintained. What is wanted is something between the present suburban railway, with its great distance between stations and its infrequent service, and the impossibly-slow tramway. The public welfare demands this change; not in order to pass profits into the pockets of the tramway company's shareholders or the ratepayers' pockets, but because modern ideas will not tolerate much longer the unhealthy congestion, which can only be avoided if there is a first-class town-transport service such as no town yet has and because the commercial needs of large modern cities are every day demanding larger aggregations of population, greater efficiency, and therefore better health of the workers and a much more complete and rapid system of intercommunication between the several parts of the town area. These things all mean that the town must grow in area and population and that its transport service must be speeded up and added to in many ways. Our tramways and our railways fail to grasp the significance of these things. The railways do not yet realise that the true measure of the distance between home and office is the average time taken from leaving the one doorstep to arriving at the other and that as a rule the walking time at the two ends and the waiting time at stations are important items in this figure. On the other hand, the tramway seems to have no idea of creating traffic, but only of providing carrying capacity when the demand makes itself felt. As a result all big towns are being fettered in their growth by a tramway policy which would have been passable in the days before steam had created the factory and brought into being the railway, the steamship, and the telegraph, but which is as useful under present conditions as the hand loom and the treadle-driven spinning wheel. What is wrong with town transport are the fundamental axioms of British tramway policy. These were born in the days of the horse car and should have no place in the present.

EFFECTS OF SUPERHEATED STEAM ON CAST-IRON PIPE.*

BY W. CAMPBELL AND J. GLASSFORD.

IT has been repeatedly observed that cast-iron fittings in superheated steam pipe lines have been subject to a form of corrosion which causes them to swell, become brittle, and fail. The worst specimens completely disintegrate, breaking down to a friable mass which may be crumbled in the fingers. It is also known that other cast-iron fittings have been used in superheated steam pipe lines for years without showing signs of corrosion. It was the object of this investigation to determine: (1) The nature of the corrosion. (2) Why some cast irons corrode, while others do not. (3) How the corrosion can be minimised.

The effect of superheated steam on cast-iron and cast-steel fittings was made the subject of a symposium at the Boston meeting of the American Society of Mechanical Engineers in December, 1909. At this meeting Ira N. Hollis stated: "Fittings have developed cracks and small changes of shape after a few months of actual service. Fittings exposed separately to superheated steam at a temperature exceeding 500° Fah., have shown a permanent increase of some dimensions. The tensile tests of pieces cut from fittings that have failed in service indicate in some cases the possibility of permanent loss of strength."

He does not consider the demonstration of loss of strength of fittings after long service with superheated steam as either complete or conclusive evidence that the superheated steam caused the loss. An 8in. × 6in. × 6in. tee carrying steam at 175lbs. pressure and 500° to 580° Fah., began to fail in 14 months. A chemical analysis gave carbon, 3·47 per cent.; manganese, 0·10 per cent.; phosphorus, 0·366 per cent.; sulphur, 0·062 per cent.; silicon, 1·41 per cent. The tensile strengths of six pieces taken from different parts of the tee were found to be 12,646lbs., 14,295lbs., 26,080lbs., 27,270lbs., and 28,280lbs. per square inch. It was supposed to be air

* Presented at the International Congress for Testing Materials.

furnace, gun iron. Samples cut from another fitting that had failed showed no loss of strength. Hollis concludes that the failures were due to the strains caused in the fittings by the expansion and contraction of the long pipe lines in which they were placed, and that the superheated steam had nothing to do with it.

Arthur S. Mann, at the same meeting, stated that "extra heavy fittings and valves" have been used in a number of instances for superheated work. After a short time, six months or even less perhaps, cracks make their appearance, valves leak, seats become loose, castings grow in length and surface cracks become so large in size and in number that the casting is removed from the line. An ordinary, commercial extra heavy flanged tee, 8in. inside diameter, with a body ⅞in. and flanges ⅝in. thick, made of common iron having a tensile strength of 18,000lbs., will fail with superheated steam at 175lbs. pressure and 577° Fah. temperature (200° superheat). Within a year the inner surface will have a network of cracks, some of which will increase in depth until they extend through the body. The flanges will crack outward from the bolt holes and the fitting will become dangerous. He has found even steel fittings have failed with superheated steam. Out of 25 steel gate valves not more than four were fairly tight after one year's service. Some defects in the castings developed, allowing steam to pass straight through the walls.

Mann concludes that superheated steam does not of itself initiate defects and it is not supposed that the sound metal undergoes a change, either chemically or structurally, but, if there is an initial defect, superheated steam is active in developing it. It is his opinion that silicon is the most injurious element present in the iron and that, though it is at present going too far to say that every high silicon iron will fail and that every low silicon iron will prove successful, there is much evidence pointing toward the correctness of such a surmise. He concludes that the remedy for the trouble is in the use of a high quality of cast iron.

Figs. 1 and 2 show two cast-iron fittings, a plug cock and a flange, which failed. They had been in use on the outlet side of a separately-fired superheater for about two years and carried steam at 50lbs. to 75lbs. pressure and at a temperature of 800° to 900° Fah. The superheater was in use for six days a week and cooled down over Sunday. The cock was the most seriously affected. It had swelled, cracked, and broken open as if by pressure from within. The metal at the point A was so friable that it could be crumbled in the fingers. It was black in colour, with little metallic lustre, and was readily attracted by a magnet. Strangely, the metal on the opposite side of the cock was apparently unaffected. The mould mark was parallel to the sides, but which side was uppermost when the cock was cast could not be determined. The flange, Fig. 2, was corroded on the steam side as shown, but instead of expanding it showed an erosion of material of 16in. on the inside and diminishing from this to nothing at the circle where the flange was protected by packing. The thread on the inside of the flange was corroded through, and was almost as friable as the centre of the cock.

In order to follow the changes which occur and the effect of composition and structure when cast iron is submitted to superheated steam, a number of specimens were heated in superheated steam at 425° C. (800° Fah.) and 95lbs. pressure, for 30 and then 90 days, and their increase in size and weight and their microstructure recorded. Another set was heated in air to 425° C. and cooled down to room temperature 72 times and examined. The specimens treated are given in the accompanying table.

The first lot, heated for 30 days, consisted of samples 1, 2, 4, 18, 19, 20, 22, 23. No distinct measurable growth was observed except in the case of sample 20, which increased in length 3·7 per cent. It also showed the maximum increase in weight of 1·4 per cent. The second lot, heated for 90 days, consisted of samples 3, 5 to 17, and 21, on which measurements were made. In addition specimens of the first lot which had been heated for 30 days were included for microscopic study only. The increase in length was irregular, with a maximum of about 2 per cent., while the increase in weight was more irregular and reached a maximum of 1·95 per cent. in the case of No. 14. These results, while indicating that some change had taken place, were not enough to draw any conclusions. Under the microscope it was seen that the changes were mainly superficial. Therefore, the main stress must be laid on the microscopical study of the specimens.

Specimens Treated.

	Silicon Per Cent.
1.—Washed metal	——
2.—White cast iron for malleabilising	0·64
3.—No. 264, steel as cast, 0·35 C. and 0·66 Mn.	——
4.—No. 644, malleable cast iron	0·88
5.—No. 800, 1¼in. diam. sand cast	0·35
6.—No. 801, 1in. square sand cast	0·45
7.—No. 802, 1¼in. diam. sand cast	0·70
8.—No. 803, 1¼in. diam. sand cast	0·95
9.—No. 804, 1in. square sand cast	1·25
10.—No. 805, 1¼in. diam. sand cast	1·35
11.—No. 806, 1in. square sand cast	1·95
12.—No. 807, 1¼in. diam. sand cast	2·00
13.—No. 808, 1in. square sand cast	2·19
14.—No. 809, 1in. square sand cast	2·5
15.—No. 795, 1in. square sand cast	1·48
16.—No. 796, 1in. square sand cast	1·70
17.—No. 797, 1in. square sand cast	1·89
18.—No. 644, 1in. square pipe iron	1·75
19.—No. 657, No. 3 foundry pig	2·0
20.—No. 660, silvery pig	5·5
21.—No. 799, gun iron	——
22.—No. 784, cock superheater	2·13
23.—No. 784, flange superheater	2·29

Washed Metal.—The normal structure shows the usual coarse eutectic-like mixture of cementite and pearlite. Being

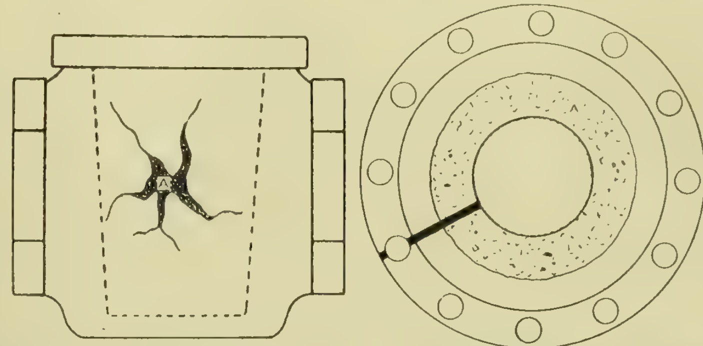


FIG. 1.—CAST-IRON PLUG COCK WHICH FAILED IN SUPERHEATED STEAM AT 800° TO 900° FAH.

FIG. 2.—CAST-IRON FLANGE CORRODED IN SUPERHEATED STEAM.

treated for 30 and 90 days causes oxidation of the surface. Cracks caused in breaking off the specimens from the original piece are found to be filled with oxide also.

White Cast Iron for Malleabilising.—Treated 30 and 90 days in superheated steam and by alternate heating and cooling in air gave similar results to the above. The only change is normal oxidation of surface.

No. 264.—Steel. Similar results, surface oxidation only.

No. 644.—Malleable cast iron, surface oxidation only.

No. 800.—The normal structure consists of fairly large, thin flakes of graphite, a little cementite, the whole in a ground mass of pearlite.

The 90-day treatment caused the usual surface oxidation, but in addition parts of the surface were swollen up and blistered by oxidation which has followed the coarsest graphite flakes. The alternate heating and cooling in air also gave some oxidation at the outside following the coarsest graphite.

No. 804.—The treatment in air mainly results in surface oxidation. Being heated for 90 days in superheated steam produces a new structure at the outside in addition to the normal oxidation. The oxidation follows the coarsest of the graphite flakes, but around this we find a white border (presumably ferrite) forming an envelope to the whole. This new constituent must be produced from the pearlite.

Nos. 805, 806, and 807 show a similar structure at the outside, increasing in intensity with the silicon content. Decomposition very marked; white borders to the oxidised-graphite flakes very pronounced.

Nos. 795, 796, 797, and 644 are fine-grained irons. All show the regular surface oxidation after 90 days' treatment, but no white envelope. No. 660 shows long graphite plates set in a ground mass of silico-ferrite with dots of cementite.

The 30-day treatment caused a marked change, while 90

days caused the mass to become split up with planes of oxidation following the original graphite. The ground mass has altered and has precipitated a new constituent as a border to the oxidation planes. The whole has undergone a profound change.

No. 779, gun iron.—Normal surface oxidation with occasional penetration following some coarse graphite flake.

Nos. 784 and 785.—Cock and flange previously referred to. Marked change after 30 days and more after 90 days' treatment. Around sides and especially at the corners, oxidation follows graphite. The treatment in air resulted in the usual surface oxidation.

Conclusion.—White cast iron, steel, malleable cast iron, all show the same type of oxidation on treatment with superheated steam. The specimens have a regular skin of oxide which also fills any cracks that may be present.

The grey cast irons, up to 0·95 per cent. silicon, show a similar surface oxidation, but, in addition, there is a slight penetration of oxide following the coarsest of the graphite flakes.

Specimens 795 to 657, containing silicon 1·48 to 2 per cent., show the same change. The other lot, 804 to 809, containing silicon 1·25 to 2·50 per cent., show the above, the penetration increasing with the silicon content, and a new white constituent is precipitated around the oxidation planes. This is extreme in the case of the silvery pig, No. 660, with 5·5 per cent. silicon.

It is natural to conclude, therefore, in the case of the cast irons, the increase in silicon is attended by increase in corrosion. Were it not a fact that No. 657 with 2 per cent. silicon stood so well, a further conclusion that the finer the graphite plates the less the corrosion would be justifiable, and this would fit in with practical experience that good gun iron stands up under superheated steam exceedingly well in practice.

WESTINGHOUSE GEARED TURBINES FOR BATTLE-SHIPS.

IN the course of a communication to "The Times" on the subject of the Melville and Macalpine and Westinghouse turbines and gears, Mr. George Westinghouse states that he now has designs under preparation for turbines and gears for battle-ships of the Dreadnought class for the American navy, and it has been found that, by properly constructing a high-speed turbine with a novel governing apparatus for admitting steam to the nozzles of the impulse part, a water-rate economy at low powers for cruising speeds can be attained vastly superior to that of any other type of marine engine, either turbine or reciprocating, accounts of which have so far been published. As an illustration, he gives the following comparison: A battle-ship of the Utah or Florida class of the United States Navy as now fitted has eight Parsons turbines requiring together 850,000 blades. With his new type of turbine, with reduction gears, there will be required four turbines having less than 60,000 blades. The weight of the Parsons turbine machinery is over two and a half times that of the new high-speed turbines and gears performing the same amount of work with a saving of a very good percentage of steam at full speed and a very large one at low speed. The size, weight, and form of these turbines, which can be started when cold, admit of their quick inspection and of the making of ordinary repairs aboard ship, while the saving in weight of the machinery and boilers of a battle-ship is estimated to be sufficient to provide for two more large guns with additional armour protection and store of ammunition. It is estimated that the saving in fuel when run at cruising speeds would increase the cruising radius of any battle-ship compared with another vessel fitted with Parsons turbines by at least 30 per cent. He has now under construction a small turbine intended for use as an auxiliary on a sailing vessel. It will have a maximum of 750 h.p. with 200lbs. of steam, and its weight will be less than 1½lbs. per horse-power, while that of the gearing of a double-reduction type required for a very low-speed propeller will not exceed 5lbs. per horse-power.

Submarine Disaster.—Another British submarine disaster, involving the loss of 15 lives, occurred in the early hours of Friday morning last off Dover. The "B 2," while engaged with other vessels, was run into by the Hamburg-American liner "Amerika," and sunk. Only one member of the crew was saved.

METHOD OF PRODUCING SOUND INGOTS.*

BY SIR ROBERT HADFIELD, F.R.S.

OWING to the trouble which has been experienced by railroads, especially in countries where low temperatures prevail in winter time, it has become a necessity to look more carefully into the matter of obtaining sound rails, free from piping, blowholes, and other defects. This in its turn means that the ingots from which the rails are made should also be quite sound and free from piping, segregation, or other defects. The improved method is applicable to ingots for other purposes, whether of the ordinary square, oblong, round, or other form.

In view of the rapid production of the large quantities of steel ingots required for a modern rail mill, whilst the production of a "sound" ingot may not be so easy as it seems at first sight, yet attention may be drawn to the subject with advantage. Perhaps the question has not received as full investigation as should have been the case. Moreover, apart from the question of soundness, the waste experienced under the present condition of manufacture is very considerable. Therefore, any system which shows how to reduce the loss by waste and scrap is one of more than ordinary interest to the steel maker, as this means not only a better product but a more economical one.

The question of producing sound steel is as important a factor in meeting the requirements of the times as ever it was. By sound steel is generally meant material free from (*a*) segregation, (*b*) blowholes, and (*c*) piping. Unless these requisites are fulfilled, trouble and breakdown of the rolled or forged material produced from the ingots may occur in some stage of its history. Fortunately, as a rule, the remedy which obviates or overcomes any one of the difficulties tends to improve all. For example, steel which is sound and free from blowholes is less liable to segregation or intermingled slag, and the ingots made therefrom, if properly fed, will have the defects under (*c*), that is, piping, largely reduced.

Many simple devices as well as complicated arrangements have been suggested and tried to overcome the difficulties in question—as, for example, fluid compression from the top, also from the bottom; feeding the settling by gas-generated heat; compressing or squeezing from the sides, and many other devices which have given more or less satisfactory results. There are, however, some disadvantages in these systems, amongst others, the expense of application owing to the heavy cost of apparatus.

For some years the author has been working at methods which appear to him to be simple yet efficient. In view of the great importance of obtaining sound material, a general description of these methods may be of interest. A system of this kind, with suitable modifications, is applicable to the manufacture of sound ingots from which to make rails and other products.

The production of ingots of sound steel, whatever may be the temper or hardness of the steel, that is, mild, medium, or hard or special steels, is important. This point has long been recognised in Sheffield in the manufacture of special steels, both for small and large ingots of crucible cast steel, in which the upper or top portion is provided with a fireclay top or "dozzler"; in other words, the ingot is "dozzled." The ingots dealt with in the present paper are chiefly those of medium size, such as used for rail production. They may be termed neither small nor large; that is, they are medium sizes and weights, varying from, say, half a ton to, say, two and a half or three tons each, and from, say, 8in. or 10in. to 20in. or 24in. square. The chief object of this paper is to deal with this special method, as full descriptions of various other processes have already appeared in technical literature—that is, relating to the Whitworth, Harmet, Riemer, Illingworth, Robinson, and other processes.

In confirmation of the author's views as to the desirability of obtaining absolutely sound steel, free from blowholes, piping, and segregation, he quotes the following from Mr. B. Talbot's excellent paper, "Segregation in Steel Ingots."† At the end of this paper Mr. Talbot says: "In my opinion it

* Abstract of paper read before the Iron and Steel Institute, October, 1912.
† "Journal of the Iron and Steel Institute," 1905, No. II., pp. 204, &c.

would be well worth while for other investigators interested in the manufacture of higher carbon steel, such as for rail, tyre, and similar purposes, to follow up these results with a view to proving whether a more uniform and regular steel is not thereby obtained, a result well worth the few pence per ton the aluminium would cost. Perhaps the chief result to be looked for would be the decreased amount of crop end that it would be necessary to cut off from the top of the ingot, due to the greater solidity of the top and the lessened amount of segregation in this top part of the ingot. This alone would undoubtedly pay for the cost of the aluminium added, without considering the more regular quality of the finished product as a whole."

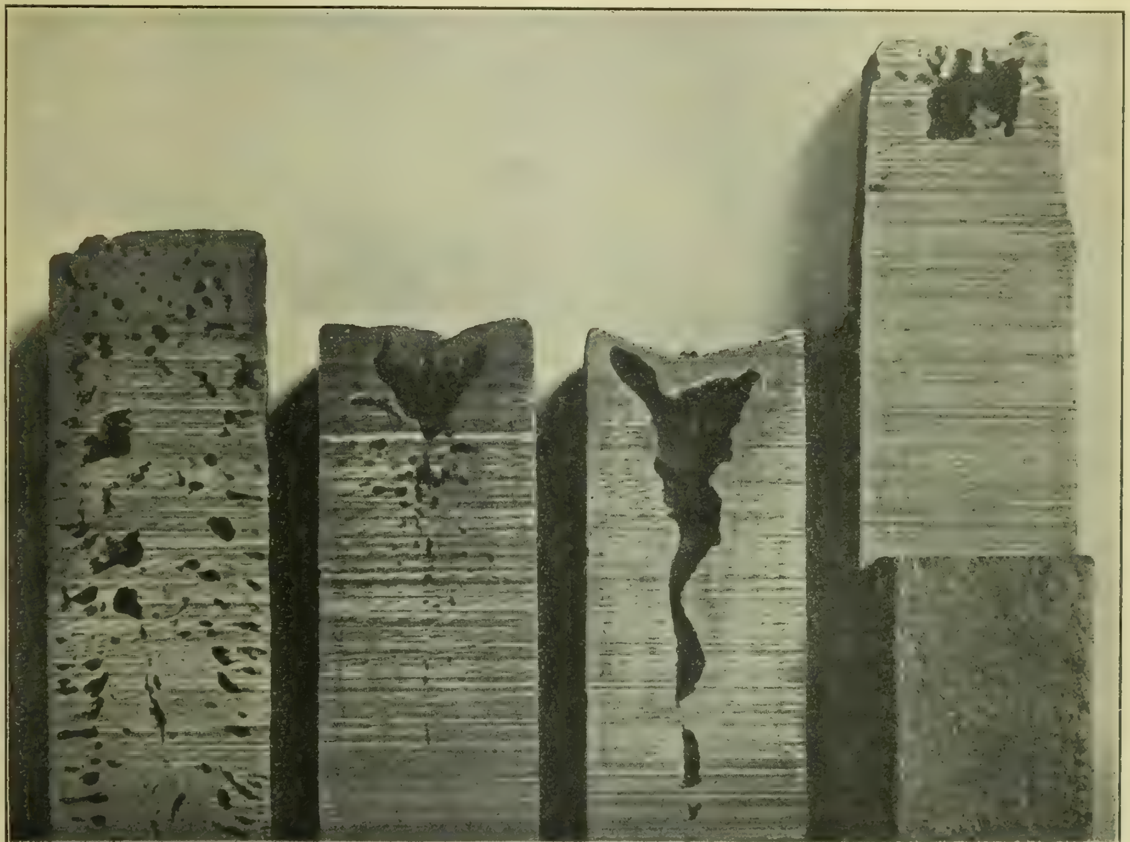
This is exactly the point so strongly insisted upon by the author of this paper, namely, that with piping steel the quality is raised as regards greater soundness and less segregation. To get these full advantages it is necessary to have a method of properly feeding or filling up the settling which would otherwise be produced by steel having such piping tendencies. The author believes the method now described satisfactorily meets these requirements, both as regards improving the quality of the material and also cheapening production, by making an ingot which, by being sound, offers less waste.

Amongst others, Prof. Henry M. Howe has dealt with this question of segregation and piping in some interesting papers, including those on "Piping and Segregation in Steel Ingots,"* and "The Influence of the Conditions of Casting on Piping and Segregation as shown by means of Wax Ingots."† The author will not go into these in detail, but would call attention to the interesting results obtained by Prof. Howe with regard to studying the condition of piping and segregation occurring in wax ingots, made with a view to show that in the cooling of fluid steel poured into ingot moulds their behaviour is similar.

At the Hecla works, Sheffield, of the author's firm, large quantities of special steels are made, in which it is essential to have perfectly sound material, free from the segregations previously referred to (*a*), (*b*), and (*c*). The methods now described have enabled the desired object to be fulfilled, both cheaply and efficiently. Moreover, it has the important advantage of enabling not only soundness to be obtained, but also a much larger percentage of the ingot to be safely used. As will be seen from the results of the experiments described, in many cases no less than 92 per cent. of the fluid steel in the mould is made utilisable, and this at small expense.

Granted in the first instance, therefore, that we are dealing with sound piping or settling steel, which is easily obtainable by ordinary care in manufacture, there seems to be no reason why the ingots should not be sound, free from blowholes, piping, and segregation. This being so, rails or other articles rolled from such ingots should be of the highest grade. It is true that large quantities of rails as now made are of excellent quality, but it is just the "tenth" case which it is important to improve. It is the bad heat here and there, the bad ingot now and then, which give the fatal rail which in service fails, involving catastrophe and all the troubles consequent upon such disasters. The methods described in this paper appear to offer a solution of this serious problem.

Fig. 1 shows the upper portion of four small ingots, each about 4in. square and 30in. in length, which were made to illustrate and test the question of soundness and piping. No. 1 shows the steel as poured into the mould without any solidifying addition. This probably represents much current practice, for the reason that at present methods to take away the piping are not used, therefore piping steel is avoided. The author has been told by a rail maker abroad that he required steel which neither rose in the moulds nor piped, a most difficult matter to accomplish in practice, besides theoretically incorrect. No. 2 shows the same steel as used in No. 1 quietened by the addition of 0·036 per cent. of aluminium. This is still not altogether sound. No. 3; to this was added more aluminium, namely, 0·09 per cent. The steel here is quite sound, but pipes deeply.



No. 1. No. 2. No. 3. No. 4.

FIG. 1.—UPPER PORTIONS OF FOUR SMALL INGOTS (4 INCHES SQUARE) MADE TO ILLUSTRATE AND TEST THE QUESTION OF SOUNDNESS AND PIPING.

The ingot maker appears, therefore, to be in a dilemma. If he makes his steel so that it will not settle, then it is unsound, like No. 1. If he makes it sounder, like No. 2, this pipes, and so is still not satisfactory, and there is much waste. No. 3 is quite sound, but the piping is almost as bad an evil as the unsoundness shown in No. 1.

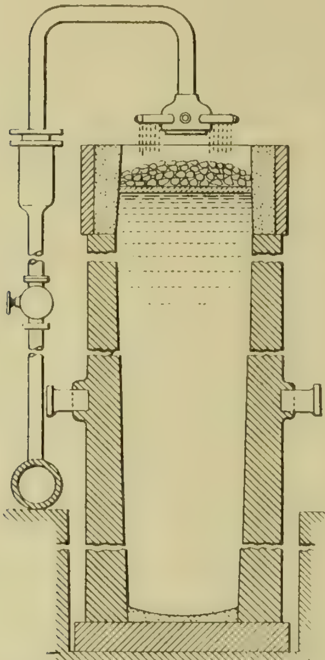
To overcome this difficulty, the methods described in this paper seem to be those best suited to give the desideratum of sound material from piping steel. Ingot No. 4 represents the same steel of the sound type used for ingot No. 3, but furnished with the proper feeding top referred to in this paper. It will be noticed that the ingot is not only sound but free from piping. The object in many steelworks seems to be to try and avoid a steel which pipes or settles. This really arises from the natural desire to avoid the trouble and expense of making preparations for dealing with piping steel. The desideratum in the author's opinion is "piping steel" which should be properly fed.

The following is a description of the author's method of casting steel ingots, castings, &c., which ensures soundness,

* Preliminary paper read at the London meeting of the Iron and Steel Institute, July, 1906.

† Read at the New York meeting of the American Institute of Mining Engineers. April, 1907.

freedom from piping, and absence of segregation: The method of carrying out the process is shown in Figs. 2 and 3. As will be seen, this consists in heating the fluid steel in the upper part of the ingot or other mould and maintaining it in a liquid condition by the combustion, in contact therewith, or in close proximity thereto, during the cooling and shrinkage of the metal in the lower part of the mould, of solid fuel—for example, charcoal—by means of a blast of compressed air which is caused to impinge on the fuel while this is directly or indirectly supported by the metal below; and the interposition of a layer of fusible material, such as cupola slag, which has little or no injurious action on the metal, between the metal and the fuel. This slag largely prevents radiation of heat, the loss by which is much greater than ordinarily supposed to be the case. Fig. 4 shows the ingots being poured, with the feeding apparatus, blast, &c., in operation. Suitable modifications of the process can also be employed.


FIG. 2.—APPARATUS EMPLOYED IN PRODUCING SOUND INGOTS, SHOWING THE BLAST BLOWING DOWNWARDS ON THE CHARCOAL.

In Fig. 3 the upper portion shows the charcoal. Then comes the layer of slag about 1½in. in thickness. The blank and dotted portion represents the fluid steel in a 15in. ingot mould. The sand or other suitable top to provide the feeding head portion is inserted in the moulding box fixed on to the top of the ingot mould itself. Whilst the ingots can be cast as at present, that is, large end down, this particular design shows the small end of the ingot downwards. There is no doubt this is the better method, as by the small end forming the bottom portion, cooling takes place more quickly, causing the steel to congeal there and thus reduce the amount of feeding required later on from the upper portion of the mould. Fig. 5 shows how the same method is applied to ingots with the larger end at the bottom.

The cost of carrying out the method is trifling compared with the large saving effected by reducing loss and waste of material. Moreover, the quality of the product is improved; for example, in making rails produced from such ingots, not only is there less discard, but the material is sounder. During the last few years many thousand tons of ingots have been made by this patented process, which has been found of great advantage.

As a specific example, it may be mentioned that ingots

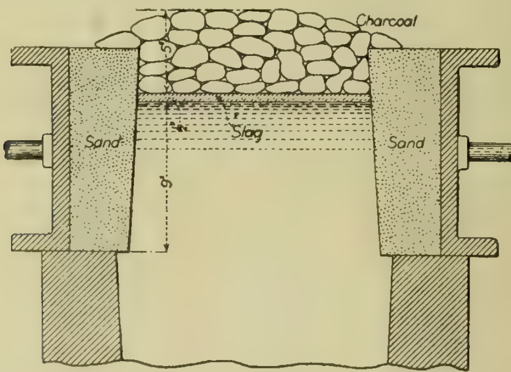


FIG. 3.—METHOD OF MAKING THE INGOTS. 15IN. MOULD.

have been made, weighing about 5,000lbs. each, in which the piping and discard do not amount to more than about 7 per cent. This small loss is not the only advantage, the chief one being that material is obtained which is quite sound and free from hidden pipes or other defects on the whole length of the ingot. The system can be applied equally well to either smaller or larger ingots, for all kinds of purposes, and for ordinary or special steels.

It is estimated that on a large output the saving by this method is from about 8s. to 12s. per ton. Thus, on a large tonnage of hundreds of thousands of tons annually, there would be a very considerable saving each year, as well as obtaining sound ingots free from blowholes, piping, and segregation.

In this experiment even the segregation usually noticed was almost entirely absent, only a few inches below the feeding head placed on the top of the ingot. At about 4in. below the surface of the sinking head the percentages of sulphur and phosphorus were practically the same as in the original steel, namely, about 0·03 per cent. each.

The following is a description of the ingots made from heat No. 9376—2185 steel: The sand head was 14in. square where


FIG. 4.—POURING THE INGOTS. EITHER TOP OR BOTTOM POURING MAY BE EMPLOYED.

it joined the ingot, tapering to 9in. square in a length of 16in. The steel was filled up in the sinking head to a depth of 14in., the remaining 2in. of sand head being filled with a layer of ground slag, having a thickness of about 1½in. The slag was

TABLE I.

Total Weight of Ingot.	Weight of Sand Head.	Weight of Sound Ingot.
Cwts. Qrs. Lbs.	Cwts. Qrs. Lbs.	Cwts. Qrs. Lbs.
38 3 0	2 2 10	36 0 18
(4,300lbs.)	(290lbs.)	(4,050lbs.)

This is equal to a waste of about 6·7 per cent.

put on the molten steel, then the heating carried out by means of the charcoal and blast in the manner described in the

patent specifications. The head was afterwards cut off the ingot, and was found to be free from piping or segregation.

The steel "fed" well, practically the whole of the molten steel in the head having descended bodily to feed the cooling shrinkage of the ingot. The head was drilled and analysed in order to find out if there was segregation. The results are shown in the following table. It will be seen that even

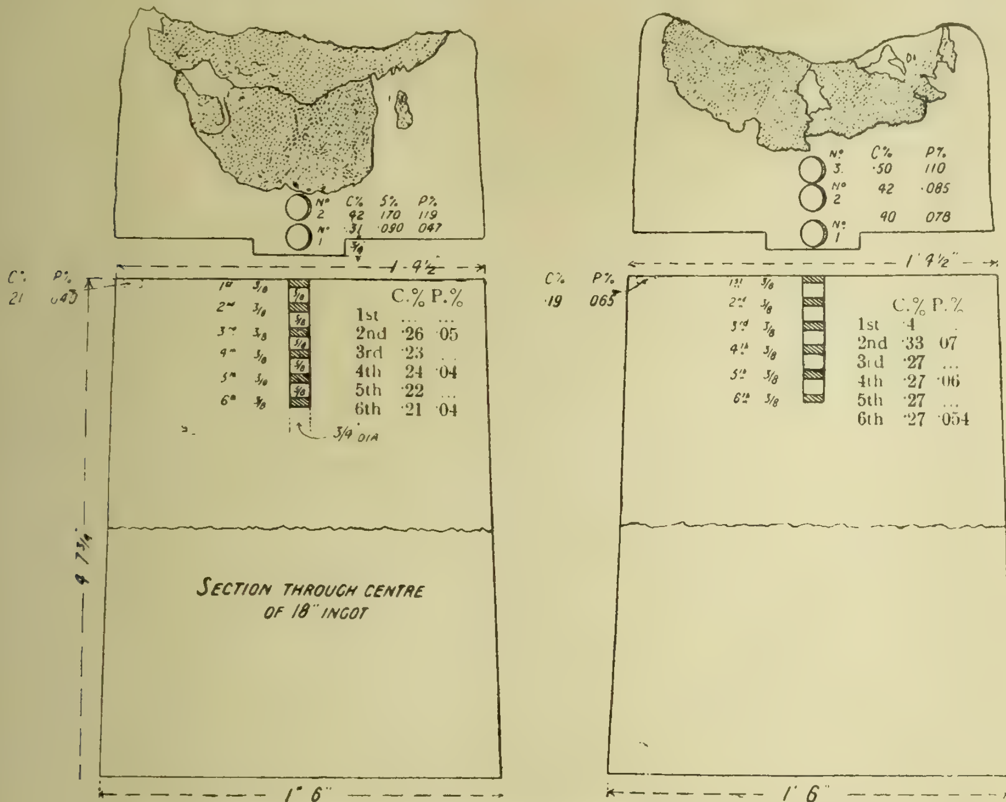


FIG. 5.—SHOWING METHOD AS APPLIED TO INGOTS WITH THE LARGER END AT BOTTOM.

TABLE II.

Position of Test-piece below Surface of Feeding Head.	Analysis.		
	Carbon Per Cent.	Sulphur Per Cent.	Phosphorus Per Cent.
"A," 1 inch below	1·41	0·175	0·135
"B," 2 inches below	1·20	0·12	0·10
"C," 3½ inches below	0·59	0·041	0·041
"D," where ingot itself commences...	0·50	0·033	0·037

"C" is almost normal in its composition, and "D," a little lower down, has practically the same analysis as the bulk of the ingot. The original analysis in this heat, as shown by the test ingot, was: Carbon 0·50 per cent.; silicon 0·16 per cent; sulphur 0·033 per cent.; phosphorus 0·037 per cent.; manganese 0·80 per cent.

This ingot with the sinking head described is a still further advance in the improvements effected in this matter, the segregation being very slight. It would appear that 93 per cent. of this ingot may be utilised for commercial purposes.

The following further experiments with this method were carried out. Two heats were made of mild and ordinary steel. In the former the carbon was 0·20 per cent., silicon 0·40 per cent., and manganese 0·60 per cent.; in the latter, carbon was 0·45 per cent., silicon 0·50 per cent., and manganese 0·80 per cent. The ingots were prepared in the manner described, that is, sufficient cupola or similar slag was placed upon the upper portion of the molten steel in the ingot mould, then charcoal and blast applied. Each ingot was provided with a sand top, placed at the top of its ordinary length of the cast-iron mould. The following were the results obtained:—

Mild Steel.—Seven ingots were cast from heat X9428—1843, and seven cast from heat X9438—1843. Total weight, 6 tons, 17 cwts., 2 qrs. Forged March 25th, 1908.

Ordinary Steel. — Seven ingots were cast from heat X9387—6, and seven cast from heat X9396—6. Total weight, 6 tons, 17 cwts. Forged March 24th, 1908.

These ingots forged well in each case, and the billets produced therefrom were sound and satisfactory in other respects.

In the experiments made it was found that, with the exception of 8·8 and 7·9 per cent. waste, respectively, practically the whole of the remaining portion of the ingots represented saleable and serviceable billets. The same results may be obtained with either smallor large ingots.

From the results obtained in the finished product great improvement was found over the methods ordinarily practised, whether as regards saving in waste or improving the quality of the material. These ingots were heated and rolled into rails in the ordinary manner without any trouble.

To bring the whole of the work briefly before the members, the author has prepared Fig. 6, on which are shown—

(*a*) The head cut off a 15in. ingot, showing sound fracture and practically no segregation. The head portion represents only 8 per cent. of the total weight of the ingot.

(*b*) The rail rolled from the ingot *a*
Total length of rail, 64ft.
Total length of rail free from piping and segregation, 62ft. 7in.

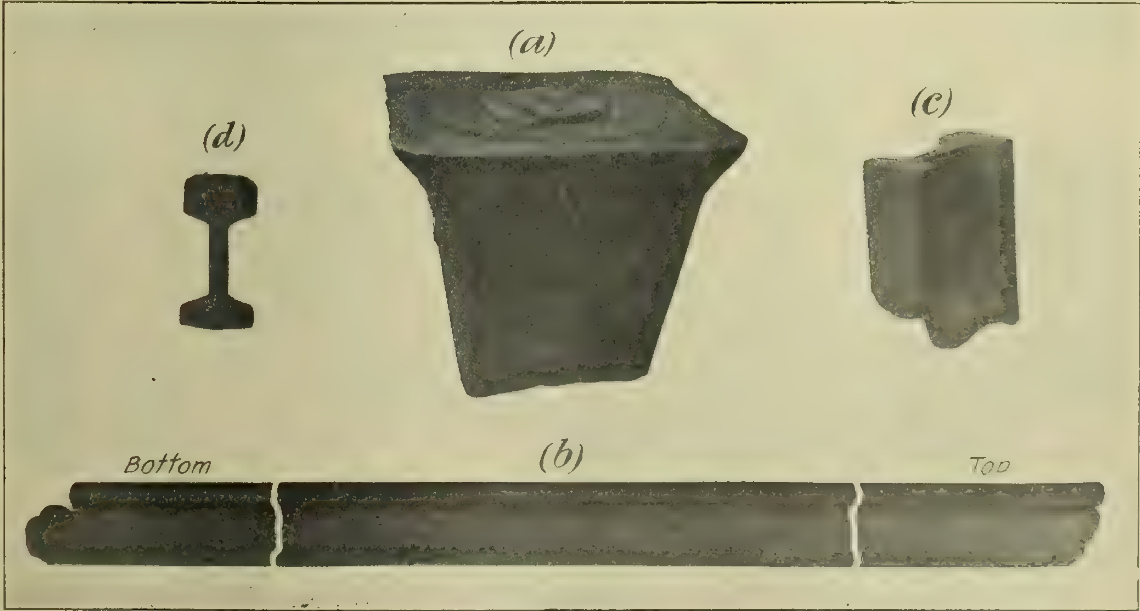


FIG. 6.

(*c*) Rail discard, weighing 24lbs., from the portion immediately under the machined surface of the head, shown in Fig. (*c*), that is, from the most unfavourable portion. It will be seen that the rail is quite sound.

(*d*) This soundness is further proved by the etched section taken from the top of the rail shown in Fig. (*e*).

TABLE III.

	Tons.	Cwts.	Qrs.	Lbs.	Per Cent.
Head scrap	0	8	0	0	6·0
Billet scrap	0	1	2	0	1·0
Forge waste	0	2	2	0	1·8
125 billets	6	5	2	0	91·2
					Total waste,
	6	17	2	0	8·8 per cent.

TABLE IV.

	Tons.	Cwts.	Qrs.	Lbs.	Per Cent.
Head scrap	0	7	3	0	5·6
Billet scrap	0	1	0	0	0·7
Forge waste	0	2	0	0	1·6
126 billets	6	6	1	0	92·1
					Total waste,
	6	17	0	0	7·9 per cent.

Although most of the results shown in this paper relate to ingots cast with the small end at the bottom of the ingot mould, there is no difficulty in applying the system to ingots cast in the manner generally practised, that is, with the larger end at the bottom and the smaller end at the top of the mould.

A further experiment was made in which an ingot was cast generally in the manner described in this paper, but nine minutes after casting the head portion was filled up with molten steel, and no air blast or charcoal used. The result was unsatisfactory, showing that this method would not take the place of the one described in this paper.

Another experiment was also made in order to ascertain the nature of an ingot using slag, but without the feeding device mentioned in this paper. The ingot was poured in the ordinary way, and a layer of fine ground slag put on the top. No charcoal, and therefore no blast, was used. The ingot piped and was excellent for soundness. The weight of the discard was, however, considerably greater, being about 12 per cent. to 14 per cent. Moreover, and this is an important point, the segregated portions of the steel did not rise to the top of the ingot so freely. The material was impure, and segregated down to a much lower point.

As regards the time required for ingots to become set, it may be interesting to describe the following experiment carried out at the Hecla Works: Ingots 9in. and 18in. square were cast. In the former case, No. 1515C material, having a composition of 0·20 per cent. carbon, and 1·25 manganese, was used; in the latter case, No. 1978A material, 0·40 per cent. carbon, and 1·34 per cent. manganese.

To determine the condition of the interior mass, a thin iron rod was inserted in the casting at short intervals after casting. The following data is interesting, showing the time required for fluid steel in ingots of this particular size to become "set":—

TABLE V.

9-inch Ingot.		18-inch Ingot.	
Time after Casting.	Distance set up the Ingot from the Bottom.	Time after Casting.	Distance set up the Ingot from the Bottom.
Minutes.	Inches.	Minutes.	Inches.
5	4	25	6
10	6	40	13
18	40	55	55
22	45	60	58
	Complete Solidification.		Complete Solidification.

The author takes this opportunity of thanking Messrs. I. B. Milne, T. G. Elliot, W. J. Dawson, and others, for the assistance they have given in carrying out this research, the labours of which have been considerable; also Mr. H. Steel and Mr. E. H. Saniter, of Messrs. Steel, Peech, & Tozer, Ltd., The Ickles, Sheffield, for their assistance in connection with the rolling of most of the rails referred to in this paper.

In conclusion, to sum up briefly the results of this research, it may be said that in order to obtain sound rolled or forged products, for example sound rails, there must first be sound steel in the ingots themselves. This means that it is necessary to use steel of piping nature, consequently the ingots from such piping steel must be properly fed. No doubt there are other suitable methods besides those described in this paper for obtaining such sound ingots, but it is doubtful whether these can favourably compare in simplicity, cheapness of operation, and in other respects. The author trusts, however, by means of the information now set forth, it will be seen that an attempt has been made to arrive at and place upon a scientific basis the underlying principles concerning the casting of sound steel, the manner in which it cools, segregates, and pipes.

COAL DUST EXPLOSIONS.

THE Home Office committee of experts which is conducting experimental investigations into the properties of coal dust, with special reference to its danger as an explosive element, has issued a second report, which starts with the acceptance of the axiom that "the finer the dust from any particular coal the greater its inflammability." Though the true chemical nature of coal is not yet properly understood, and the researches have not been completed, some insight has been gained into the general character of the compounds forming the coal substance. Experiments have led to the conclusion that all coals contain at least two different types of compounds of different degrees of ease of decomposition; they are, in fact, a mixture of compounds, of which one readily yields inflammable gases on heating to a comparatively low temperature—with bituminous coals gases are evolved on heating to a temperature well below 600° C.—and the other requiring a higher and more prolonged duration of temperature to produce decomposition. Hence the inflammability of coal dust will depend largely upon the proportion in which the readily decomposed constituents are present, and the question arises, "Can this hypothesis be utilised to form a criterion of inflammability?" Tests which are lucidly and interestingly detailed, and their results carefully tabulated, have been made with more than 50 different coal dusts, all obtained by pulverising nut coal, and varying in their ash content between 2 and 10 per cent. The tests have shown that the presence of varying quantities of incombustible dust added to pure coal dust alters its ignition temperature to an appreciable extent, although natural ash does not exert the same influence as added ash. At this stage of their investigations, which are not yet ended, the committee feel that they have found a valuable means of discriminating between different coals in regard to the sensitiveness of their dusts to ignition. Though pointing out that the tested dusts have been ground and sieved to equal degrees of fineness, they are careful to indicate that the friability and porosity of coal and the shape of its dust particles must be taken into account as factors affecting its inflammability.

Report on Recent Aeroplane Accidents.—The Public Safety and Accidents Investigation Committee of the Royal Aero Club, after having exhaustively enquired into the circumstances of the fatal accident which occurred to Mr. R. C. Fenwick whilst flying a Mersey monoplane on August 20th at Salisbury Plain during the progress of the War Office trials, reports that it is of opinion that the accident was primarily due to the instability of the aircraft, which made it difficult to control in a disturbed atmosphere. Moreover, the point where the accident occurred is well known to be one where irregular disturbances of the air are prevalent under certain wind conditions. One of these disturbances, says the Committee, must have struck the aircraft, and the aviator eventually lost control. Concerning the circumstances attending the death of Mr. C. Lindsay Campbell, which occurred on August 3rd, whilst flying a Bristol monoplane at Brooklands, the Committee considers that the accident was due to the aviator failing to appreciate the danger of keeping the aircraft in a horizontal position after the engine had stopped, thereby losing flying speed and control of the machine. The Committee is also of opinion that since that portion of the aeroplane in which the aviator was seated was undamaged his life might have perhaps been saved had he used a helmet and belt.

INTERNATIONAL ENGINEERING AND MACHINERY EXHIBITION, OLYMPIA, LONDON.—I.

AN International Engineering and Machinery Exhibition, under the auspices and direct-control of the Machine Tool and Engineering Association, Ltd., was opened on Friday last, the 4th inst., by the Rt. Hon. the Earl of Selborne, and promises to be a success from every point of view. It is the largest exhibition of its kind ever held in Great Britain, and has been in course of preparation for the last 18 months. It may be explained that the Machine Tool and Engineering Association, of which Mr. H. G. Mackinder, M.P., is president, and Mr. Walter Deakin chairman, was formed two years ago, its object being to promote the general interest of the engineering trades in connection with exhibitions both at home and abroad, by assuming direct control over the dates of displays in Great Britain, and by arranging for united exhibitions, as far as possible, in connection with the great international efforts in various parts of the world. The scope of the association is very wide, as it embraces all the varied interests which affect the industry, and the assured success of this exhibition, its first important work, justifies the formation of such an association.

Altogether, there are some 293 exhibitors, and the weight of their exhibits is estimated at 4,000 tons, with a value of about a quarter of a million of money. No previous exhibition, we are given to understand, has contained such a weight of material, and the management are to be congratulated on having excluded the "side-show" element, a feature which has been too prominent at previous exhibitions. Stands devoted to the exhibit and sale of fountain pens, rubber stamps, and "your photograph while you wait," are all very well in their way, but one hardly goes to an engineering exhibition with the primary object of inspecting or purchasing such goods.

It is safe to say that the collection of machine tools now gathered together at Olympia represents the finest specialised machinery display ever held in this country, and we advise all our readers, who conveniently can do so, to pay a visit to the exhibition. Not that it contains many surprises; developments in design are matters of relatively small gradations, and to estimate progress we must pay attention to the details of the machines on view. The most straightforward development has, of course, taken place in the case of the ordinary lathe, the marvellous increase in the power of which has been due to the adoption of high-speed steel and cutting tools, and this also has led to the supersession of the cone pulley and belt shifting, by the all-gear head, enabling full belt speed to be employed for all diameters of work. More complex, perhaps, are the developments that have taken place in the turret lathe; for example, there are turrets admitting turners, drills, taps, and taper turners, while the automatic chuck and roller feed of the lathe permits of the handling of rough stock, and of presenting new lengths and gripping while the machine is running. Planing machines continue to grow in size and speed of cutting, boring and turning mills find increasing application; and, with hobbing and milling machines, ever-growing accuracy is being obtained in gear cutting, which in turn enables the accuracy of other machine tools to be increased. Besides machine tools, many productions from other departments of mechanical engineering are in evidence; for example, woodworking machinery and foundry equipment are well represented, together with power, compressed air, and hardening and tempering plants; bolt, nut, and screwing machines and tackle, power transmission apparatus, bearing metals, packings, and lubricants, as well as some electrical plant and numerous small tools. In short, everything which is adapted to fill the requirements of mill and workshop generally is on view at Olympia, which building, when we take into account that 192 of the exhibitors are power users, is virtually a huge workshop for the time being.

The exhibition remains open until the 26th inst., and it is our intention to notice many of the more interesting features in succeeding issues of this journal.

Fatal Colliery Winding Accident.—A cage accident which placed the lives of eight men in jeopardy and resulted in a lad being killed, occurred on the 1st inst. at the British Top Pits, Abersychan, near Pontypool. The cage was being lowered, when it caught the side. All its occupants were much shaken, the lad being thrown to the bottom of the shaft.

MINE EXPLOSIONS.

AT a meeting of the Midland Institute of Mining, Civil, and Mechanical Engineers, held at Doncaster, some interesting remarks were made with regard to the paper on the prevention of explosions in mines, which Dr. John Harger, of Liverpool, recently read at Manchester. It will be remembered that Dr. Harger advocated the lowering of the quantity of oxygen in the air and the adding of a small percentage of carbon dioxide. Prof. Hardwick, who presided, said Dr. Harger's paper, showing that the oxygen in the atmosphere had so much to do with the propagation of explosions, threw considerable light upon the fact that, while ventilation had improved considerably, unfortunately there had been little or no diminution in the number and magnitude of explosions that had taken place. The point raised as to the quantity of oxygen in the atmosphere for working was interesting. It seemed to him that the tendency of physiologists now was rather to lower the percentage. Whereas in his young days he was taught that 21 per cent. was necessary, apparently they were getting down to something like 17½, or less than that. Prof. L. T. O'Shea agreed that if they could reduce the oxygen in the atmosphere to below a certain amount, ordinary combustion would cease. That was a point which should appeal to them all, especially in districts which were subject to gob fires, because if they could bring the oxygen down to a reasonable amount perhaps they would be able to control the spontaneous ignition of coal, and so render the occurrence of these fires less frequent. But he thought the question of explosions was not on all fours with that of ordinary combustion. They wanted to know more about the relation between the quantity of oxygen present in the air and ignition under pressure. Prof. Dixon, in the discussion on Dr. Harger's paper, pointed out that he had, under certain circumstances, been able to bring about the ignition of coal dust with only 13 or 14 per cent. of oxygen, by means of electric sparks; and the apparatus which Dr. Harger used was not quite the same as ignition under the influence of a hot flame from a blown-out shot. It had been pointed out that in a large number of coal mines there was only, perhaps, 19 per cent. of oxygen at the coal face. The air which went into the mine contained 21 per cent., but it lost some in passing to the coal face. If they were going to start with air containing 19 per cent., what was going to be the quantity when it got to the face? That was a practical point which needed to be very carefully considered before they began to play with the quantity of oxygen going down the downcast shaft. Mr. W. D. Lloyd said Dr. Harger seemed to found his conclusions to a large extent on the fact that explosions, as a rule, did not travel the coal face or the return airway, where the air was more deficient in oxygen than in the intakes. But he did not seem to give full weight to another fact—that as a general rule there was not, on the faces and in the return airways, the same quantity of coal dust that there was in the intake. He emphasized Prof. O'Shea's point as to the possibility of igniting coal dust under pressure, even in a deficiency of oxygen. As regarded the amount of oxygen necessary for working, he said he had seen an analysis showing that a man with a breathing apparatus could breathe quite comfortably with only 12 per cent. of oxygen. In that particular case, however, the man was not doing any work. Whether he could have done any, without distress, was another question.

Electric Trolley 'Buses at Rotherham.—A new railless electric trolley omnibus system, connecting the villages of Wickersley, Bramley, and Maltby, with the Borough of Rotherham, was formally opened on the 3rd inst. The necessary overhead equipment has been provided at a cost of something like £1,000 a mile, as against £5,000 per mile for ordinary tramways. There are only three other trolley omnibus routes in Great Britain, namely, at Leeds and at Bradford, both of which were opened on the same day, June 20th, 1911, and at Dundee, which was opened last month. Rotherham Borough Council is the first local authority to obtain powers to run trolley vehicles outside the municipal boundary, and in this respect the system is unique. The vehicles are of the single-deck type and have each cost £725.

MILLING AND BORING MACHINE.

THE accompanying illustrations show a design of milling and boring machine, particularly applicable for milling and boring turbine casings, the invention of C. F. Shanks, of Messrs. Thomas Shanks & Co., Union Ironworks, Johnstone. The machine is of the type in which the framework is horizontally movable and includes end standards, extending

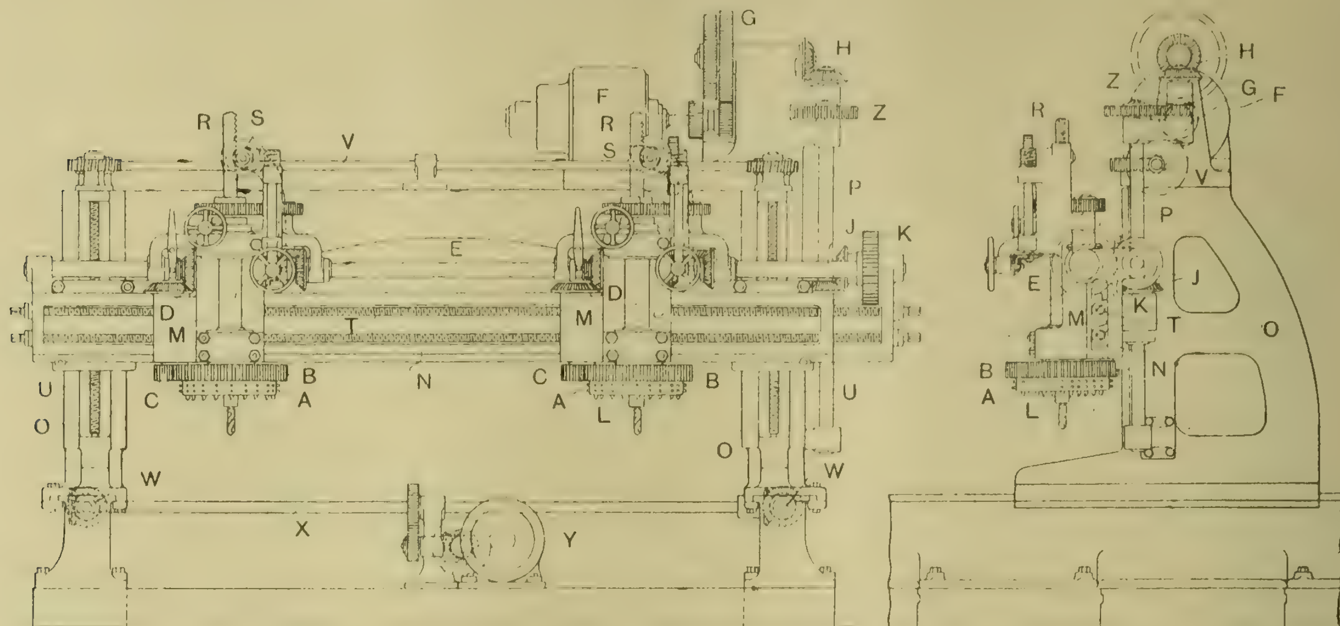


FIG. 1.—MILLING AND BORING MACHINE.

transversely of which is a frame adjustable vertically relatively thereto, to which frame are adjustably connected bracket members supporting the operating tools. Referring to the illustrations, the machine is equipped with two milling cutter wheels A disposed in a line at right angles to the direction of travel and adjustable relatively to one another, these cutter wheels being driven by gear wheels from a common shaft. As shown, the cutter wheels are mounted on bracket members M slidably connected to a supporting frame N disposed transversely of and adjustable vertically in relation to a framework which includes end standards O, and is adapted to be moved in a horizontal plane. Each cutter wheel is provided with a spur wheel B connected to a sleeve supported at its upper end by ball bearings in the bracket member M, and is engaged by a pinion C adapted to be rotated by clutch-controlled bevel gearing D from a shaft E which is supported on the frame N and is driven from an electric motor F, supported by a cross beam connecting the standards O, through spur gearing G, bevel gearing H, and spur gearing Z mounted on one of the standards O, and through bevel gearing J and spur gearing K mounted on the frame N, the bevel wheel J on the driving shaft P being slidable relatively to shaft P so as to permit of vertical adjustment of the frame N.

Coaxially with each cutter wheel A or one of each set of cutter wheels is a spindle L carrying a drill movable axially so as to project beyond the face of the corresponding cutter wheel, each drill spindle being adapted to be driven through gearing at a higher speed than the corresponding cutter wheel A, and being fitted relatively to the cutter wheel in such manner as to permit of proper feed of the drill spindle. As shown particularly in Fig. 2, the drill spindle L passes coaxially through a sleeve, and is adapted to be rotated by means of the spur and bevel gearing shown. The bevel wheels are freely mounted on the shaft E, and have clutch faces adapted to be engaged one at a time by a sliding clutch Q, rotatable with shaft E, according to the direction in which it is desired to rotate the drill spindle L. The feed mechanism for the drill spindle consists, as shown, of a rack R formed thereon and a pinion S operated by worm gearing and manually-controlled bevel gearing.

The bracket members M are adapted to be adjusted horizontally by means of screw-threaded spindles T rotatably mounted on the frame N, and this frame is adapted to be adjusted vertically by means of screw-threaded spindles U rotatably mounted on the standards O and operated by worm gearing from a shaft V, provided with a spur wheel adapted to be engaged by a sliding pinion driven from the electric motor F. The standards O and parts connected thereto are adapted to be moved relatively to stationary supports on the base of the machine by means of screw-threaded spindles W, which are rotated by means of bevel gearing operated by a shaft X which is driven by gearing from an electric motor Y. With a machine equipped with milling cutters and boring

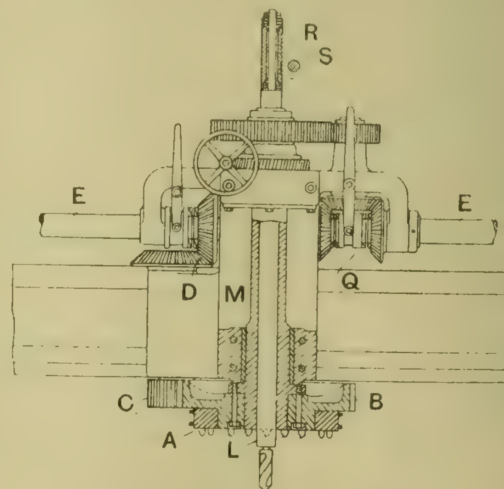


FIG. 2.—MILLING AND BORING MACHINE.

drills as above described it is possible to mill casings for turbines during the travel of the tool in one direction, and on the return motion to bore the milled surfaces.

New Great Northern Goods Locomotive.—A new goods locomotive, from the designs of Mr. H. N. Gresley, who succeeded Mr. H. A. Ivatt about a year ago as chief locomotive engineer to the Great Northern Company, has just been constructed at the Plant Works, at Doncaster. It is the first engine designed by Mr. Gresley since he took office, and is one of 10 of the same type which are being built at Doncaster. It is expected that the new engine will have a more powerful haulage capacity and a higher rate of speed than the engines now used in the goods service. The cylinders are 20in. diam. by 26in. stroke, the coupled wheels being 5ft. 8in. diam. It is fitted with Schmidt's superheater, which is being used on practically all the modern engines of the company. The total weight of the engine is 61 tons 14 cwts., and the tender is 43 tons 2 cwts.

THE INFLUENCE OF OXYGEN ON THE PROPERTIES OF METALS AND ALLOYS.*

BY E. F. LAW, A.R.S.M. (LONDON).

FOR some years the author has been urging the necessity of a fuller recognition and appreciation of the influence exerted by oxygen when present in metals and alloys; but that the subject has not received the attention which it deserves is evident from some remarks recently made by Sir Gerard Muntz. During the discussion on a paper by Hughes† before the Institute of Metals, Sir Gerard Muntz said: "There was one other point which must not be lost sight of in the study of the question—unfortunately it was generally lost sight of —namely, the question of oxygen. As far as his experience went he did not think the importance of that point had sufficiently, or at all, come home to the practical man—he would not include his scientific brethren, because one never quite knew what was in their minds; but the practical maker of metals, and more especially the practical users, had not given half enough consideration to the value of the comparison of the proportionate amount of oxygen to the other ingredients."

And again, during the discussion on a paper by Greaves‡ on the copper-arsenic alloys, the same gentleman said that "he desired to impress upon the engineering world, especially his friends in the railway world, the great importance of the question of arranging the oxygen content when they specified the arsenic content, because if they did not take any notice of the oxygen, it was not much good their taking any notice of the arsenic."

In view of the importance attached to the influence of oxygen by so eminent an authority on copper and its alloys, it occurred to the author that a useful purpose might be served by bringing forward the question before the Institute of Metals, with the object of raising a discussion which might lead to further study and a more complete understanding of the subject. It must be clearly stated at the outset, however, that the present paper does not claim to be in any way a complete study of any particular metal, but is written rather with the object of reviewing the relations of metals with their oxides from a broad and general standpoint.

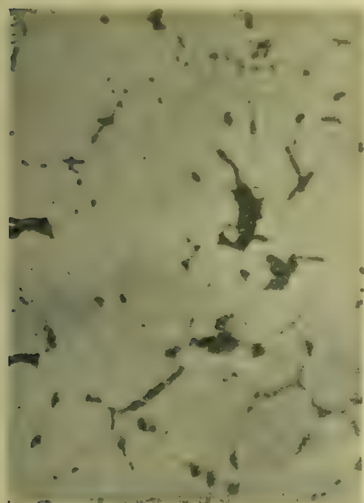


FIG. 1. BEARING BRONZE. MAGNIFIED 100 DIAMETERS. VERTICAL ILLUMINATION.

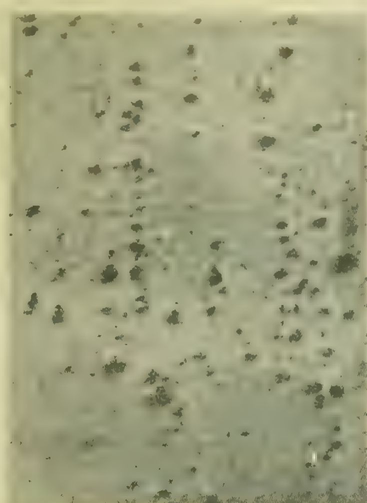


FIG. 2.—LOCOMOTIVE FIREBOX. MAGNIFIED 100 DIAMETERS. VERTICAL ILLUMINATION.

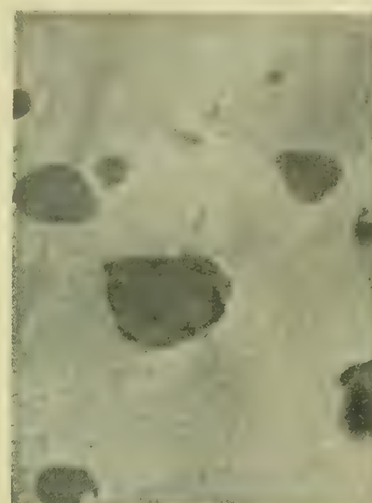


FIG. 3. LOCOMOTIVE FIREBOX. MAGNIFIED 1,000 DIAMETERS. VERTICAL ILLUMINATION.

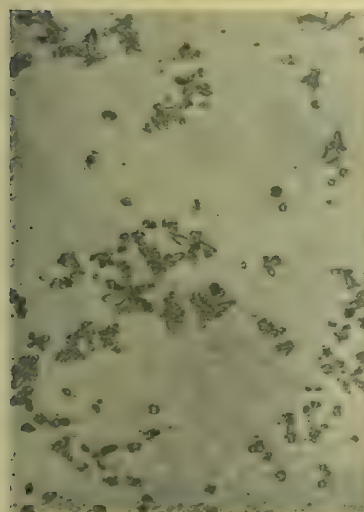


FIG. 4. OXIDISED COPPER. DENDRITES OF CUPROUS OXIDE IN EUTECTIC. MAGNIFIED 100 DIAMETERS. VERTICAL ILLUMINATION.

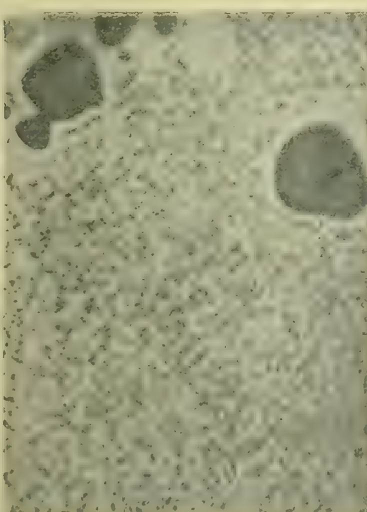


FIG. 5. OXIDISED COPPER. EUTECTIC. MAGNIFIED 1,000 DIAMETERS. VERTICAL ILLUMINATION.

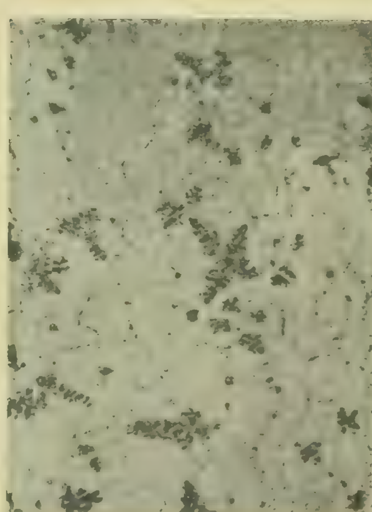


FIG. 6. SAME AS FIG. 4, BUT CONTAINING 0·075 PER CENT. ARSENIC. MAGNIFIED 100 DIAMETERS. VERTICAL ILLUMINATION.

Metallic oxides may be regarded as the natural or stable condition of existence of nearly all the metals. From these oxides the metals are won by the expenditure of energy, and they are themselves, therefore, in the nature of combustibles, and will tend to revert to their former condition with the liberation of energy. Both in the winning and working of metals, unceasing care has to be exercised in order to prevent oxidation, and the difficulties attending the successful accomplishment of this object have been overcome by the practical man with little assistance, it must be admitted, from the scientist. As the result of experiment, he has found that the addition of certain substances improves the quality of the resulting metal, and without fully understanding the true reason of the improvement, he has succeeded in presenting us with a formidable list of deoxidisers. Following the introduction of phosphorus in 1853 came manganese and aluminium, and within the last few years, silicon, magnesium, cadmium, vanadium, titanium, and boron, both singly and

* Paper read before the Institute of Metals, September, 1912.

† "Non-ferrous Metals in Railway Work," "Journal of the Institute of Metals," No. 2, 1911, Vol. VI.

‡ "The Influence of Oxygen on Copper containing Arsenic or Antimony," "Journal of the Institute of Metals," No. 1, 1912, Vol. VII.

in combination with one another. It is true that some of the metals mentioned form useful alloys, but in many cases their sole function is to deoxidise the metal to which they are added. So important is the deoxidation of metals and alloys that it would probably be no exaggeration to say that when the history of the alloy industry comes to be written the record of progress during the last 20 years will be summed up in the words, "the use of deoxidisers."

In spite of its importance, however, the scientific side of the question has been almost entirely neglected. No doubt this is partly due to the experimental difficulties attending the determination of oxygen, and it is true that one's sympathies would naturally be extended to the unfortunate metallurgist who was asked to determine the oxygen in an aluminium alloy; but it is the business of the scientist to who are unaccustomed to the examination of commercial metals and alloys would be astonished at the large volume of non-metallic matter which frequently finds its way into their composition without being indicated in any way by the chemical analysis.

Judging from those cases which have been examined, it would appear that metallic oxides (and we are not concerned here with occluded oxygen, but only with combined oxygen) are insoluble, or practically insoluble, in metals and alloys. They occur as particles, varying in size and distribution, entangled and embedded in the metal, and it is obvious that the existence of these non-metallic particles scattered throughout the metal must seriously affect its properties. One or two examples will perhaps serve to illustrate these points. Fig. 1, for example, is a polished and unetched section of a

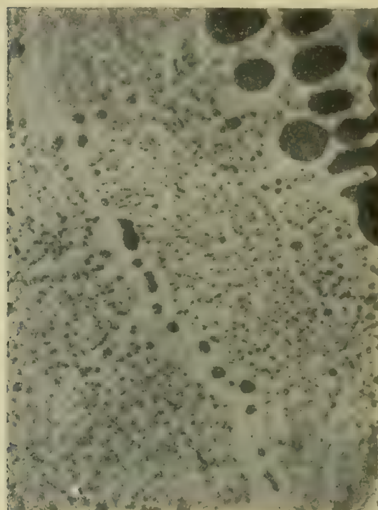


FIG. 7.—SAME AS FIG. 6. MAGNIFIED 1,000 DIAMETERS. VERTICAL ILLUMINATION.

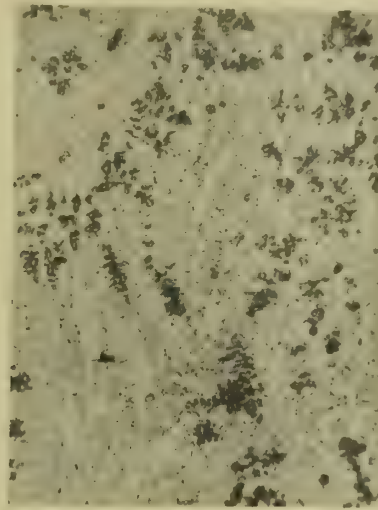


FIG. 8.—SAME AS FIG. 4, BUT CONTAINING 0·42 PER CENT. ARSENIC. MAGNIFIED 100 DIAMETERS. VERTICAL ILLUMINATION.



FIG. 9. SAME AS FIG. 4, BUT CONTAINING 2·28 PER CENT. ARSENIC. MAGNIFIED 100 DIAMETERS. VERTICAL ILLUMINATION.



FIG. 10.—SAME AS FIG. 9. MAGNIFIED 1,000 DIAMETERS. VERTICAL ILLUMINATION.

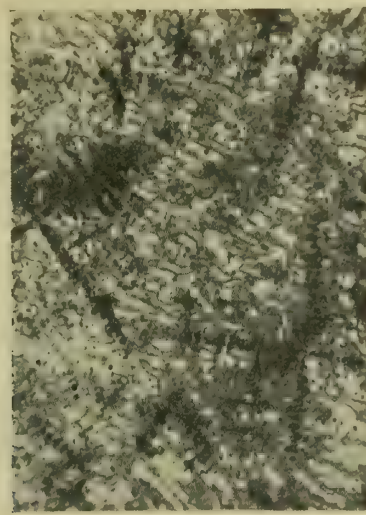


FIG. 11.—SAME AS FIG. 9, BUT ETCHED. MAGNIFIED 100 DIAMETERS. VERTICAL ILLUMINATION.

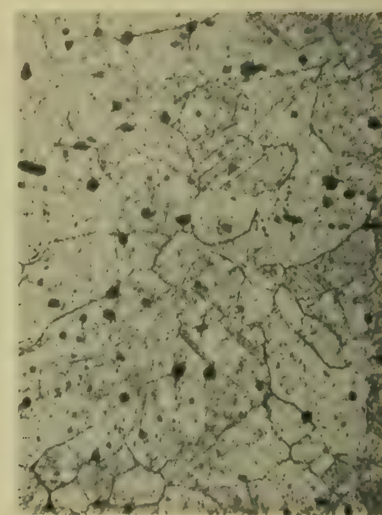


FIG. 12.—FIREBOX COPPER, ETCHED. MAGNIFIED 100 DIAMETERS. VERTICAL ILLUMINATION.

overcome difficulties, and if it can be proved (as it certainly can) that oxygen exerts a powerful influence on the properties of metals, then he must be prepared to give the subject his serious attention. A chemical analysis of copper, for example, which failed to report 0·1 per cent. of lead would be regarded as, to say the least of it, unsatisfactory, and yet it not infrequently happens that ten times this quantity of cuprous oxide, which is in many cases a much more injurious constituent than lead, is passed over without notice in the reported analysis. This is surely unscientific and illogical. Moreover, the omission is more serious than it appears at first sight, because the oxides, having lower specific gravities than the metals, occupy a larger volume, and it must not be forgotten that the influence exerted by an impurity depends upon its volume and not upon its weight. Those

portion of a bearing bronze taken from a rolling-mill. The photograph is not taken of a specially selected portion, but represents a fair average sample of the alloy. To all outward appearance the metal was satisfactory and was put into service, but it is not surprising that it had to be removed after only two hours' work, owing to excessive heating. Whether in bronze or white metal bearings, the presence of oxide will invariably cause trouble.

Figs. 2 and 3 are taken from a section of a locomotive firebox which fractured in service. This fracturing of oxidised arsenical copper has had attention drawn to it by Bengough and Hill* in their very valuable paper on the copper-arsenic alloys. The complete analysis of this sample showed the following results:—

* "Journal of the Institute of Metals," No. 1, 1910, Vol. III.

Copper	99·349
Arsenic	0·433
Lead	0·009
Nickel	0·056
Oxygen	0·115
Bismuth	trace.
Antimony and sulphur	nil.
	99·962

This is an excellent example, both of the excessive amount of oxide which is sometimes found in commercial alloys, and also of the large quantity of oxide represented by a relatively small figure in the analytical results.

While dealing with the copper alloys of this type, it must be pointed out that they occupy a somewhat unique position in regard to their relations with oxygen, and in view of their great industrial importance it may not be out of place to consider them briefly.

Three papers have recently been read before the Institute of Metals dealing more or less with the properties of these alloys, and while in no way wishing to minimise the importance of the valuable work contained in these papers, it must be confessed that a perusal of them, together with the discussions which took place at the time of their reading, leaves the mind of the reader in a state of considerable confusion as to the real nature of the alloys and the impurities which exert such a prejudicial influence. Bengough and Hill, for example, consider that the oxygen in copper-arsenic alloys occurs as arsenious oxide, while Huntington suggests that it exists in the form of a copper-arsenite. On the other hand, Johnson* declares that it exists as cuprous oxide, and goes so far as to state that arsenious oxide is reduced by metallic copper with the formation of cuprous oxide. Frequent reference is made to the eutectic of copper and cuprous oxide, which, in all the photographs reproduced, is conspicuous by its absence; and even as regards the manufacture of the alloys, the old theory that arsenic behaved as a deoxidiser has been abandoned, and some declare that it is immaterial whether the arsenic is added in the form of arsenious oxide or metallic arsenic. It is difficult, however, to find any justification for a method of procedure which deliberately adds an element which is not wanted, and must be subsequently removed if the quality of the metal is not to suffer. An additional difficulty in the way of a clear understanding of these alloys is due to the fact that published determinations of oxygen are in most cases altogether unreliable. Errors of two and three hundred per cent. are by no means uncommon.

The peculiarities which have placed these alloys in a unique position and have been the cause of so many conflicting views are, firstly, the fact that copper forms a simple series of alloys with its oxide; and secondly, that the heats of formation of cuprous and arsenious oxides are both low, and do not differ widely from one another. Hence the oxides do not form very strong combinations, but are easily reduced to the metallic state; whereas copper and arsenic combine to form one of the strongest and most clearly defined of the intermetallic compounds. The result of this is that not only is the arsenic incapable of acting as a deoxidiser, but, even if present in an oxidised condition, is actually reduced more or less completely, and combines to form arsenide of copper, which passes into solid solution. If copper-arsenite were formed it would immediately rise to the surface, as it is an easily fusible compound. There is as little likelihood of copper-arsenite being entangled in an arsenical copper as there is of phosphate of copper occurring in a phosphor-bronze.

It is interesting to note that copper containing arsenide in solution does not form the characteristic eutectic structure of copper and cuprous oxide. The oxide occurs in the massive form. This is not an isolated instance, as Hudson and the author have shown* that in the case of phosphor-copper the eutectic structure completely disappears if the copper contains a small quantity of tin in solution. It is obvious, however, that the physical and mechanical properties of the alloys are materially affected by this change in structure.

* "Journal of the Institute of Metals," No. 2, 1910, Vol. IV.

A series of alloys has been prepared, showing the effect of increasing additions of arsenic to oxidised copper, and some of the more interesting of the photographs which have been taken of these alloys are reproduced, and will serve to illustrate the changes taking place in the structure. In making these alloys, best electrolytic copper was used, and was oxidised in the crucible—no addition of oxide being made. The requisite quantity of arsenic was added in the usual way and a small ingot cast after each addition. Fig. 4 shows the oxidised copper. The eutectic composition has purposely been exceeded, and dendrites of cuprous oxide are seen embedded in the eutectic. Fig. 5 is the same sample at a higher magnification, and shows the characteristic eutectic structure of copper and cuprous oxide. Fig. 6 shows the appearance of the alloy after a small addition of arsenic. A breaking up in the continuity of the ground mass of eutectic will be observed; and Fig. 7, at a higher magnification, shows the way in which this takes place by the "balling up" of the particles of oxide. In making up this sample a content of 0·075 per cent. arsenic was aimed at, and the analysis showed 0·078 per cent. It will be noticed that even in the presence of an excess of cuprous oxide this small quantity of arsenic enters into solution as arsenide. Fig. 8 shows an intermediate stage in the process of gradual coalescence of oxide particles, with increase of arsenic, until in the sample represented by Figs. 9 and 10 the eutectic structure has completely disappeared. In this case the saturation point of arsenide in copper has just been exceeded, and free arsenide is beginning to separate out. Fig. 11 shows the same sample after etching, the free arsenide occurring as minute dark particles in the lighter-coloured solid solution.

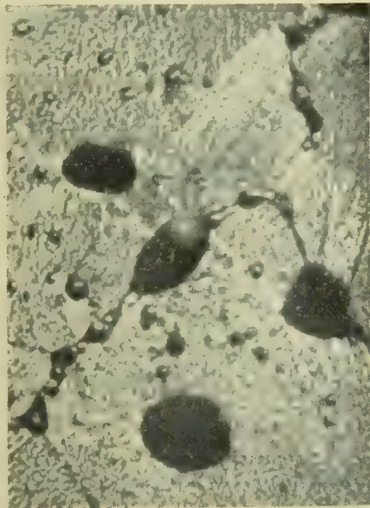


Fig. 13.—Firebox Copper. Etched. Magnified 1,000 Diameters. Vertical Illumination.



Fig. 14.—Oxidised Bronze. Magnified 1,000 Diameters. Vertical Illumination.

It will be seen, therefore, that although there are certain peculiarities connected with the occurrence of oxide in arsenical copper, it does not differ from other alloys in its susceptibility to oxidation or in the mode of occurrence of the oxide. The presence of the arsenic in no way hinders the oxidation of the copper.

The mode of occurrence of oxides in metals is naturally of great importance. As regards mechanical tests the minimum effect is produced when the oxide occurs in massive form, as in the case of the arsenical coppers just considered. Figs. 12 and 13, taken from an etched sample of a locomotive firebox, show that the oxide does not necessarily occur between the crystals although it sometimes happens that they lie on the boundary of two crystals.

The maximum effect is produced when the oxide occurs as a network between the crystals, as shown in Fig. 14, which is taken from an oxidised sample of a "special" bronze. In

* "Journal of the Institute of Metals," No. 1, 1910, Vol. III.

reality, however, this is not nearly so serious (at any rate, from the user's point of view) as the previous example, because the defect is usually made apparent by the poor mechanical tests; whereas the whole trouble with oxidised metals is that they frequently pass the mechanical tests, and only when they are put into service does the real trouble begin.

The work of Bengough and Hill with reference to the fracture of oxidised copper-arsenic alloys by reducing gases has already been referred to, and the author has shown* that the blisters produced in the pickling of thin steel sheets previous to tinning, and the fracture of hard steel under similar conditions, are both due to the reduction of oxide in the steel. Doubtless there are other cases which might be mentioned, but it is in connection with the subject of corrosion that the question is of the most vital importance.

During the last few years innumerable papers have been written on the subject of corrosion, and every imaginable influence assisting the rate of corrosion (even to the action of sunlight) has been pressed into the service of the enthusiastic investigator, until the unfortunate user, if he were ever inclined to take these papers seriously, must have given up the problem in despair long ago. Interesting as all these scientific investigations may be, there is a tendency to overlook one point of view, and that happens to be the point of view of the practical man. It cannot be too strongly urged that the difficulties which beset the users of metals and alloys are not so much those of uniform and normal corrosion. These are more or less in the nature of known factors, and can be made the basis of calculations. It is the cases of abnormal corrosion—pitting and local deterioration, in most cases due to the presence of non-metallic impurities—which upset all calculations and cause so much trouble. Whereas theories regarding the nature of electrolytes and the differences of potential between the constituents of alloys have been discussed at great length, the author cannot recall a single instance in which an analysis of the material investigated has included a figure for oxygen, or even suggested its presence. Nor do there appear to be any determinations of, or even references to, the differences of potential between metals and oxides, in spite of the fact that they far outweigh the relatively small differences existing between the separate metallic constituents of alloys. Here we are not dealing with millivolts, but with measurements of far greater magnitude, and as an illustration of the practical utility of the difference of potential between a metal and its oxide we need go no further than the ordinary electric accumulator. It is the more surprising that this subject has not received more attention, considering that the injurious effect of imperfect protective oxide coatings is well known and has been studied at some length. In the case of steel the influence of oxide has received slightly more attention; but by no one has it been more fully realised than by Mr. C. P. Sandberg, for whom the author has carried out a number of tests. Plates of ordinary steel, and plates of the same steel rolled from ingots which have been deoxidised by the addition of silicon, have been exposed to the London atmosphere for more than three years, and have been carefully cleaned, examined, and weighed at intervals of six months. The results have shown that the rate of corrosion of the ordinary plates is 24 per cent. greater than that of the deoxidised plates; or, in other words, the life of the deoxidised steel as shown by these tests is 24 per cent. longer than that of the ordinary steel. Under normal conditions of service this figure would be exceeded, because the artificial removal of the oxide every six months exposes a fresh surface, and the plates start corroding under the same conditions. Under ordinary circumstances the more corrodible plates would scale more frequently than the less corrodible ones, a fresh surface being exposed each time to the full action of the corroding agents. This effect has been observed in the case of experimental plates, which have been exposed for more than six months without cleaning, and in which automatic scaling has taken place. Another example which may be mentioned of abnormal corrosion due to oxide is to be found in the case of oxidised welds, which have been described in some detail by Merrett, Digby, and the author.†

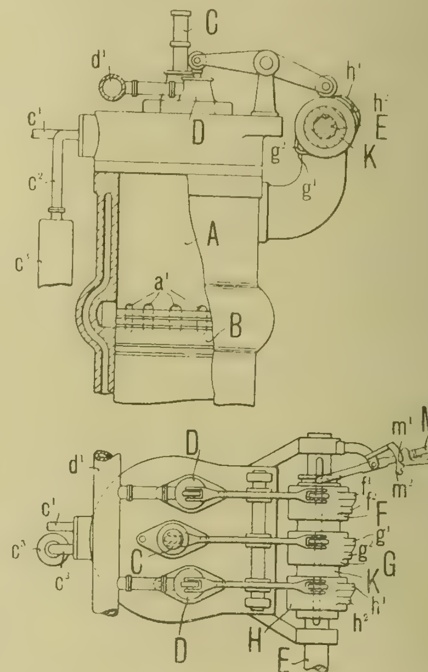
* "Journal of the Iron and Steel Institute," No. 1, 1906, Vol. LXXIII.; and No. 2, 1907, Vol. LXXVI.

† "Journal of the Iron and Steel Institute," No. 1, 1911, Vol. LXXXIII.

From the evidence which is constantly coming under his notice, and of which this paper is an attempt at a brief summary, the author is firmly convinced that experiments on corrosion which omit to take into account the presence of oxides in the metals experimented upon are of little value; and that in practical work it is equally important that the presence of oxides, whether introduced during the manufacture or subsequent treatment of the metal, should be considered. The manufacturer has found that the greater fluidity and superior qualities due to freedom from oxide are matters of great moment both in the casting and after treatment of the metal; but the user has not yet realised that from his point of view a perfectly deoxidised metal is of equal, if not greater, importance.

KRUPP'S TWO-STROKE CYCLE INTERNAL-COMBUSTION ENGINE.

In 2-stroke cycle internal-combustion engines used for the propulsion of vehicles, ships, &c., in which the ignition of the fuel is effected by the heat of compression (Diesel type), and which have exhaust ports governed by the piston of the engine, it is necessary that the speed of the engine shaft shall be capable of being regulated within wide limits. The known 2-stroke cycle internal-combustion engines do not,



Figs. 1 and 2.—Krupp's Two-stroke Cycle Internal-combustion Engine.

however, comply in general with this indispensable requirement for marine engines. On the contrary, it is found in the case of these engines that for the reason set forth below, the necessary final pressure at the end of the compression stroke and consequently also the final temperature at the end of the compression stroke necessary for the ignition of the fuel, can no longer be obtained in the cylinders when the speed of the engine shaft is reduced, so that some of the ignitions fail to take place, and serious breakdowns in the working of the engine occur. The reason for this disadvantage is, that in the known 2-stroke cycle internal-combustion engines the operation of the air valves is effected by one and the same controlling cam, while the engine shaft is running at different speeds.

When an engine of this class runs at a high speed, a definite uniform compression of the scavenging and charging air is produced at the instant in which the engine piston just shuts off the exhaust slots in the wall of the cylinder. If, on the other hand, the engine runs at a low speed, the pressure of the scavenging and charging air in the supply pipe to the air valve drops, since the air pumps attached to the engine shaft now supplies a smaller quantity of air for a certain time; in addition thereto, the air valves for scavenging and charging air and the exhaust ports remain open for a longer time during one revolution. On account of this, the initial compression pressure falls, that means the pressure of the charging air in the cylinder at the instant in which the engine piston just shuts off the exhaust ports, and consequently the final com-

pression pressure falls, when the engine is running at a lower speed than that for which the air valves are constructed. To obviate this disadvantage the arrangement illustrated herewith has been designed and patented by the Krupp Company, of Kiel-Gaarden, Germany, in which means are provided for varying the opening of the air valves to correspond to the different speeds of the engine shaft.

Fig. 1 is a side elevation, partially in section, of a 2-stroke cycle internal-combustion engine intended for the propulsion of ships, and Fig. 2 is the plan view corresponding thereto. A is the cylinder and B is the piston of the engine. The exhaust ports which are arranged in the cylinder wall are denoted by a^1. C is the valve for spraying in the fuel, and D are two valves for the supply of scavenging and charging air. The fuel valve C is attached to a fuel supply pipe c^1, and is connected by a second pipe c^2 to a compressed air reservoir c^3 which contains the air for spraying the fuel. The air valves D are connected by a pipe d^1 to an air pump which is driven directly off the engine shaft. The valves C, D are operated through valve levers from cams F, G, H on a special regulating shaft E. The cams F and H are similarly constructed and are each provided with large cam faces f^1 and h^1 which are intended to operate the air valves D at high speeds, and also with smaller cam faces f^2 and h^2 which are intended to operate the air valves D at low speeds. In a similar manner the cam G for the valve for spraying in the fuel is also provided with two differently-sized cam faces g^1 and g^2 (which for the sake of clearness are not drawn in the correct position in Fig. 2) and of which the larger one g^1 and the smaller one g^2 operates the fuel valve when the engine is running at high speed and at low speed respectively. The cams are mounted upon a common sleeve K, which latter is connected to the regulating shaft E by a key and key-way so that it rotates with the shaft, but can be moved in an axial direction thereon, this sleeve being capable of being locked in one of two positions on the shaft by means of an operating lever M pivoted to the frame of the engine. Notches m^1 and m^2 for engaging the operating lever which locks the cam sleeve K are so arranged that when the pawl of the operating lever is in engagement with the notch m^1 the large cam faces f^1, g^1, h^1 are brought into operation, and when the pawl is in engagement with the notch m^2 the small cam faces f^2, g^2, h^2 are brought into operation.

The action of a 2-stroke cycle engine in general is well known, and need not therefore be explained. It will suffice therefore to point out the conditions which arise when the cam sleeve K is adjusted for low or high speeds. When the engine is running at high speeds, the sleeve K will be brought, by operating the hand lever M, into such a position that the cam faces f^1, g^1, and h^1 operate the valves corresponding to them. Assuming that the length and arrangement of the cam faces f^1, g^1, h^1 be suitably chosen for a certain (high) speed, the engine will run in a reliable manner at this speed without breaking down. If, on the other hand, the speed of the engine shaft be reduced, the disadvantage previously described will take place, so long as the same cams f^1 and h^1 be used for the operation of the air valves. This disadvantage can be avoided with certainty by the arrangement of the smaller cams f^2 and h^2, which, when the engine is running at low speeds, are brought into their operative position by moving the cam sleeve K by means of the lever M. Similar reasons also determined the use of a second cam g^2 for the operation of the fuel valve, since if only one cam g^1 be provided the fuel valve C would always remain open a long time, a comparatively large quantity of compressed air would pass out of the reservoir c^3 into the cylinder, and cause a strong cooling down of the contents thereof. By the provision on the fuel valve gear of a second cam g^2, which can be brought into its operative position at low speeds, the additional advantage is secured that an economy in the compressed air used for spraying in the fuel is effected, and that only a slight cooling down of the contents of the cylinder takes place.

In the engine under notice the conditions are so arranged as to secure as favourable an action as possible both at high and low speeds, that is to say, under those working conditions which occur most frequently and continue longest, the intermediate stages not being taken into consideration. If it be desired to also take account of the intermediate stages between full speed and slow speed this may be accomplished by providing, in addition to the controlling cams for full and slow speeds and between them, one or more controlling cams for mean speeds.

A NEW MACHINE FOR ALTERNATING LOAD TESTS.*

BY B. P. HAIGH, B.SC.

BEFORE, and especially since, the date of Wöhler's classical tests, it has been widely recognised that the endurance of metals and other materials under repeated stress differs from that which they exhibit when the load is steadily applied. In many cases, parts of machines made of ductile metal have been found to fail in a brittle manner after repeated loading, and the apparent change in the nature of the material has been attributed to fatigue. It is extremely difficult to design a machine in which the load is applied by mechanical means with a high frequency, since the masses of the various parts in combination with their unavoidable springiness introduce inertia stresses which affect the load. The actual stress may thus be considerably more, or generally less, than the calculated value. Nevertheless, several machines working with comparatively high frequencies have been constructed, some of these being arranged for rotary bending tests and others for direct pull.

During the discussion that followed Mr. Eden's recent paper on the endurance of metals, references were made to the use of an alternating magnetic flux for producing a pulsating pull in a specimen, and some brief notes were also contributed by the author describing a machine of this class which had been in use in the James Watt Engineering Laboratories of the University of Glasgow (where it was

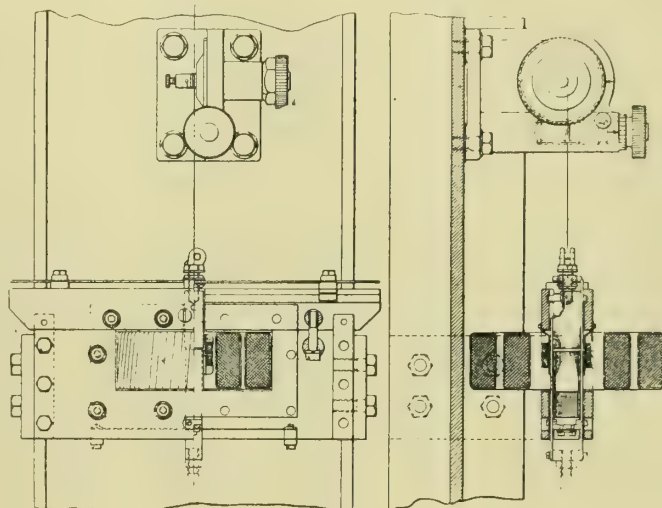


FIG. 1.

constructed) for some months. The present machine is of small size, being intended primarily for testing wire with direct pulls varying up to about 1 cwt.

The construction of the machine is shown in detail in Fig. 1, and its principle is illustrated diagrammatically in Fig. 2. The lower end of the specimen W is attached to the armature A. This is a laminated block of iron, supported on flat springs giving freedom for vertical motion in a small range, directly over the pole P_1 of the magnet. A magnetic flux (indicated by chain lines) is produced by the large coil C, and passes across from the armature to the main pole P_1, thence back to the subsidiary poles P_2 and P_3 by means of the laminated yoke. The total air gap in the circuit is made small, so that a coil of moderate size is sufficient to produce a very strong flux in the air gap, developing a strong pull between the pole face and armature.

When the density of the flux on the pole face is B lines per square centimetre, the magnetic pull per square centimetre is given by the expression (Maxwell's law)—

$$F = B^2/8\pi \text{ dynes per centimetre}^2.$$

Taking the area of the pole face as A sq. cm., the total magnetic flux is (A × B) lines, and the electromotive force induced in each turn of the magnetising coil is—

$$E = 4{\cdot}44\ c\ (A \times B)\ 10^{-8} \text{ volts},$$

where c is the frequency of the alternating current supplied, measured in complete cycles per second. The magnetic pull

* Abstract of paper read before Section G of the British Association at Dundee, September, 1912.

F is therefore proportional to the square of the ratio of volts to cycles—*i.e.*,

$$F = k\ (E/c)^2.$$

This holds good so long as a constant proportion of the total magnetic flux passes across the gap—*i.e.*, so long as the leakage flux which passes between the sides of the armature and the pole P_1 is a constant proportion of the whole. If this were strictly the case, the pull would depend only on the ratio volts to cycles, and it would be immaterial whether the air gap varied or not. In practice, however, the leakage flux varies with the gap, and it is therefore important to keep the leakage as small as possible. The leakage flux is proportional to the width of the gap and to the periphery of the vibrator, while the useful flux is proportional to its area; hence it follows that it is important to work with approximately constant gap; and, further, that a large machine (in which the "ratio" of the periphery to the area is small) is easier to design than a small one, such as that which has been built. Even in this small machine, however, the pulsating pull is fairly constant with respect to variations in the air gap. The pull increases somewhat as the gap is reduced, and it is sometimes necessary to manipulate the machine skilfully so as to keep the gap constant in spite of slight instability. In a larger machine this would be unnecessary, as the "leakage factor" would be constant.

The small coil C^1 is connected directly to a sensitive voltmeter, and acts like the secondary winding of a transformer. It is introduced so that the voltmeter readings from which the load is deduced may be as far as possible free from leakage errors. The coil is therefore wound with fine wire very close to the edges of the pole face, so that the greater part of the leakage flux passes outside the coil. In this way the constant k in the equation for the pull becomes almost independent of the size of the gap.

It is not difficult to control the air gap within the desirable limits when the specimen is not too long. A low-power microscope fitted with a graduated scale in the eye-pieces is handy for the purpose, and allows the range of vibration under any given load to be read off at the same time that any adjustment is being made. When a test of long duration at a given pull is being carried out, it is more convenient to employ an ammeter to measure the magnetising current. As this current is directly proportional to the mean length of the air gap (for a given flux density), it is a very simple matter to keep the two constant.

If it were possible to avoid eddy currents in the pole piece P_1 and armature, the strength of the magnetic pull would not depend upon the frequency, but only on the ratio voltage to frequency. In practice, however, the laminations are more or less short-circuited, and eddy currents are induced which drive the flux to the outside of the pole, increasing the leakage and reducing the pull. It is necessary to use fairly thin stampings, effectively insulated from one another, in order that the flux may be uniformly distributed over the pole face.

Before proceeding to describe the method of standardising the machine, by which the results are obtained accurately without the need of tedious calculations of the leakage factor, it may be well to point out the double purpose of the flat springs S_1 S_2 which carry the armature. The springs are primarily arranged so as to guide the armature A between the poles P_2 and P_3, keeping its lower face parallel to that of the pole piece P_1. By using springs instead of lubricated guides one ensures the absence of friction, which might easily become a large (and variable) quantity. When working with high frequencies, even the air resistance of the armature and its attachments becomes a measurable quantity, although generally so small as to be negligible. To hold the armature in position only requires the use of very light springs, as the lateral stresses are small so long as the air gaps on the two side poles P_2 and P_3 are equal. Thus the lower spring S_1 is of quite light material, similar to that used in clock springs, and serves only to keep the armature central. It is attached to the armature by the side plates, which pass on either side of the main pole P_1, and is held at the ends by clips D, D attached to the frame holding the yoke. The upper spring S_2 is made of much heavier material, however, as it serves the extra purpose of compensating the inertia forces required for accelerating and decelerating the mass of the armature. Although the mass and amplitude are both small, the force required is considerable, as the frequency may be high. The stiffness of the springs may be adjusted to suit the frequency of the test by moving the clamping saddles E E inwards or outwards on the upper part of the frame.

It appears desirable to work with a wave of sine shape, as this means that the test is being carried out at one definite frequency, and not with a combination of several frequencies corresponding respectively to those of the fundamental and several harmonics. When current is supplied from an alternator having star-connected 3-phase windings, no third harmonic is present in the electromotive force wave; and, as even harmonics are very seldom met with in machines of ordinary design, we need only consider the effect of fifth and seventh harmonics. If the electromotive force wave has a fifth harmonic having, say, 5 per cent. of the pressure of the fundamental, and a seventh harmonic having, say, 7 per cent., then the wave of flux will have corresponding harmonics of reduced amplitude. The flux produced by a given electromotive force is inversely proportional to its frequency, and in the case assumed the fifth and seventh harmonics will each have only 1 per cent. of the amplitude of the fundamental. If the maxima of the fluxes of different frequencies occur at the same instant (due to a flat-topped electromotive force wave), the increase in the pull due to the presence of each harmonic is only 2 per cent. of that of the fundamental, while other relative positions of the waves give still smaller effects. As the real values of the electromotive force harmonics may be kept much smaller than those assumed above, their effect may be taken as almost negligible, hardly influencing the maximum value of the pull and producing only a slight unevenness in the steeper parts of the curve. A small search coil for checking the wave-form by means of

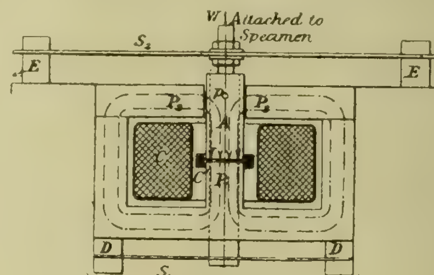


FIG. 2.

an oscillograph is wound round the pole piece P_1 (Fig. 2) as closely as possible to the coil used for determining the useful flux. As shown in the drawing, the spring S_2 (which is, in reality, in two parts) is clipped between nuts on a screwed spindle secured to the top of the armature. By adjusting the two nuts together, the rest position of the armature is moved upwards or downwards as required. The armature may be held in its central position while this adjustment is made by means of the pin p passing through the frames; and in the same way the saddles may be adjusted sideways without any chance of the armature being drawn against either of the lateral poles P_2 or P_3.

The method of standardising the machine consists essentially in determining the mean value of the pull of the magnet. When this is known, together with the wave shape of the magnetic flux, the maximum value of the pull is readily deduced. Thus, when the flux follows a sine wave, the pull follows a sine wave of double frequency, and the mean value is exactly one-half of the maximum. The ratio is easily calculated for other waves when the wave-form has been determined by the oscillograph. In general, there are six forces acting on the armature under working conditions and also when standardising. These forces are (1) the magnetic pull, (2) the pull of the specimen (or standard spring), (3) the inertia forces, (4) the force of the control spring, (5) the weight of the vibrator and its fittings, and (6) the air resistance. Under working conditions we can equate No. (4) to No. (3) and No. (5), and may neglect No. (6); the pull in the specimen is then equal to the magnetic pull. When standardising the machine the specimen is replaced by a standard spring, and the inertia of the system is increased by attaching a comparatively heavy mass to the armature. The standard spring is extended until the heavy weight is lifted and the armature "floats" at its normal

level, vibrating in only a very small range, as the extra mass is so great in comparison with the pull of the magnet. We may now apply a modified form of Newton's law, which states that when a body is vibrating in a constant range with any one or more frequencies, the sum of all the constant forces applied must be zero. The pulsating unidirectional pull of the magnet may be regarded as made up of two components—firstly, a constant pull equal to the mean value; and, secondly, an alternating pull varying in a sine wave. In the case of the armature, the four constant forces acting upon its mass, together with the heavy mass attached, are: The mean value of the magnetic pull, the pull of the standard spring, the force of the control spring (nil), and the weight of the armature and the mass attached. Equating the sum of these four to zero, we deduce that the mean value of the magnetic pull is equal to the pull in the spring less the total weight, while standardising the voltage and frequency are noted, and also the extension of the standard spring necessary to overcome the mean value of the magnetic pull. The mean value of the pull is thus directly comparable with the standard weight, the values being proportional to the extensions produced. It is, of course, necessary to use a number of standard weights, so as to verify the proportionality of the extension of the standard spring to its load within the working range. By repeating the process with different values of the air gap, it is possible to check the increase of pull when the gap is reduced. The pull appears to vary about 2 per cent. over a range of ½ mm., but it is difficult to determine the figure exactly, as the measurement

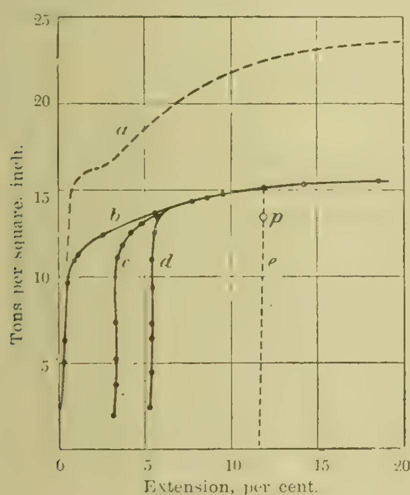


FIG. 3.

of the pull is subject to an error of about ½ per cent. either way.

Up to the present only a limited number of materials have been tested under pulsating load in the machine, and it may suffice to give some preliminary results obtained from two materials standing at almost opposite extremes of the long range of carbon steels used in the form of wire. The first of these is a low carbon (0·15 per cent.) annealed wire, breaking under a steady stress of about 24 tons per square inch, with 20 per cent. extension, while the second is a hard-drawn steel of higher carbon (0·47 per cent.), breaking at about 160 tons per square inch with 1·7 per cent. extension.

The results obtained from the ductile material are shown in Fig. 3, in which curve *a* represents the autographic stress-strain diagram obtained with a steady load. This test was made with Dr. Barr's wire-testing machine, adjusted so that the duration of loading was 15 minutes. Curve *b* represents the extension of the same material under a pulsating load applied with a frequency of 62 per second. It is clear that extension begins at a much earlier stress, and that the maximum load does not exceed 16 tons per square inch, which is very close to the yield point under steady load. It is also remarkable that the percentage extension, which is "corrected," as already described, so as to be expressed in the usual manner, is very approximately the same for the two curves. Curve *b* represents the greatest extension that has been obtained from a number of specimens. Many of these broke earlier, but this may be attributed to lack of skill in manipulation. It will be understood that it is not easy to maintain a constant air-gap when extension is so rapid as indicated by the flat curve *b*. The fractures were carefully examined, and do not appear to differ noticeably from those obtained with steady load; in both cases the characteristic local extension of a ductile material was formed. Curves *c* and *d* represent the stress-strain diagrams obtained with pulsating load when the specimen had been previously strained with steady pull and released, leaving respectively 3 per cent. and 5 per cent. permanent extension. The curves rise steeply, and afterwards follow curve *b*; the total extension was again 20 per cent. It is noticeable that curves *c* and *d* are rounded off as they join *b*, and that the rounding appears less with 5 per cent. than with 3 per cent. initial extension. When part of the extension has been carried out with pulsating load, and then subsequently continued, curve *e* is obtained. There is no apparent rounding off at the junction of curves *e* and *b*, but extension recommences sharply when the load reaches its former value. An interval of rest of 24 hours does not appear to alter this result. When the specimen has been extended by pulsating load, and the load is then somewhat released, say 10 per cent., to the point represented by *p*, it does not appear that any further extension occurs—at any rate, after a very short period has elapsed. The reduced load may be re-applied at least 2,000,000 times without further extension, and when fracture occurs it is at the grips, probably due to hammering.

Hard-drawn metals are still more difficult to grip, as the stresses are so high that slipping, on the one hand, and fracture by hammering, on the other, are very difficult to avoid. This will be understood when it is considered that the strength of such hard-drawn steel wire is four to five times as great as that of ordinary steels. In many cases specimens, therefore, fracture at the grips; but, on the other hand, a number fracture in the middle, and it appears that the strength with a pulsating load is not greatly less than that with a steady load. Thus, the better specimens broke with a stress of about 120 tons per square inch pulsating, combined with 20 tons per square inch steady (applied with the object of minimising vibration), giving a total stress of about 140 tons per square inch, as compared with about 160 tons per square inch obtained in tests with steady load. Up to the present, no clear evidence of fatigue has been found either in ductile or hard-drawn materials, but this may be due to several failures having been attributed to accidental causes. It appears that hard-drawn wire should be suitable for investigating this phenomenon, and it is hoped to carry out tests shortly. It is clear that fatigue tests are in many cases as much dependent on the form of the specimen as on the material. Thus a large specimen of weak material may stand a greater number of repetitions of a given maximum stress than a smaller specimen of stronger material. The duration of the test is dependent on the rate of growth of a crack, rather than on any change in the nature of the material. By the use of wire of moderate diameter the time taken for the growth of a crack should be very much reduced, and any real change in the nature of the metal would be more able to make itself evident. In the absence of comparative data regarding fatigue, it would appear that ductility is not advantageous in wire subjected to a rapidly-pulsating load. On the other hand, the hard-drawn material appears to retain a greater proportion of its strength when tested under a pulsating load.

FAILURE OF A CAST-IRON STEAM SEPARATOR.

IN the course of a paper on "The Growth of Cast Irons after Repeated Heatings," read by Prof. H. F. Rugan at the recent meeting of the Iron and Steel Institute, the author gave the results of an investigation made in order to discover the cause of the failure of a steam separator in one of the large power plants in the City of New Orleans, La., while in service. The conditions it had been under while in service were as follows: When the plant was started saturated steam had been used in the pipe system, later this was changed to superheated steam with temperatures, as observed, varying from 370° Fah. to 470° Fah.; these temperatures fluctuated frequently. All fittings used in the pipe line were tested before being installed to a pressure of 300lbs. per square inch.

In order to obtain definite information regarding the

material used in the separator, seven specimens were made from the broken pieces. Three of these were from parts $\frac{3}{4}$in. in thickness, and four from parts 1in. in thickness. These specimens were turned to $\frac{1}{2}$in. diam. at the centre and threaded to $\frac{3}{4}$in. – 10 threads on the ends, and broken, with the results given in Table I.

Table I.

Tensile Test of $\frac{3}{4}$in. Metal.					Tensile Test of 1in. Metal.				
Mark.	Diameter.	Area.	Breaking Load.	Stress.	Mark.	Diameter	Area.	Breaking Load.	Stress.
V.	0·4982	0·1949	2,750	14,100	I.	0·4905	0·1888	2,220	11,750
VI.	0·5000	0·1963	2,930	14,900	II.	0·4985	0·1951	2,080	10,660
VII.	0·4945	0·1920	2,770	14,420	III.	0·5002	0·1964	2,190	11,140
					IV.	0·4940	0·1916	2,300	12,000
Mean average				14,473	Mean average... ...				11,387

The thinner metal cooling sooner shows a higher strength than the parts that were thicker, and therefore more slowly cooled. This difference in strength almost compensates for the difference in the thickness of the metal.

Classing the separator as a medium casting, and assuming that a test specimen taken from such a casting would about

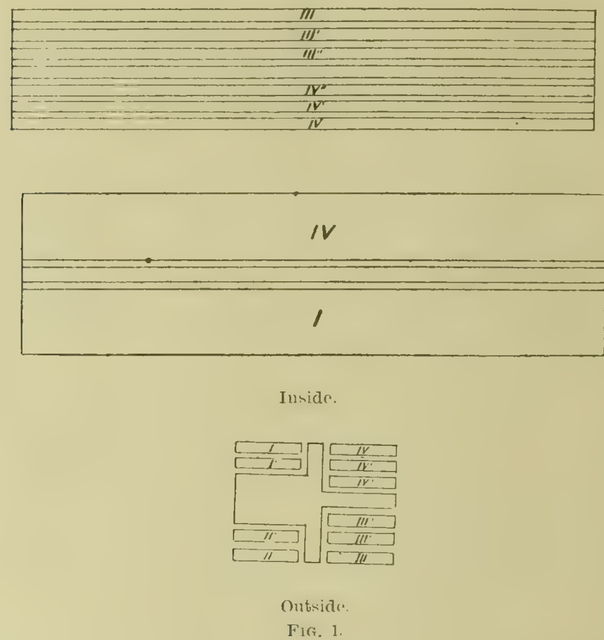


Fig. 1.

equal 90 per cent. of the strength of a test-bar cast at the time of casting, it will be seen that these samples were much lower than the strength required for medium castings in the standard specifications for cast iron, adopted by the American Society for Testing Materials, which is 21,000lbs. per square inch in a bar $1\frac{1}{4}$in. square and 15in. long.

In order to determine if any deterioration had taken place in the casting, due to the heat treatment it had received while in service, three specimens were cut from various parts of the broken pieces of the separator for microsections. These specimens were prepared with great care, every effort being made to ensure a good surface at the extreme edges where they joined the scale surface of the casting. Upon examination under the microscope, it was found that the broken-down appearance observed in previous experiments was to be seen in the casting a certain distance in from each surface. This change had permeated 0·0781in. in from the outer surface of the casting, but had not affected the metal nearly as much as it had upon the inner surface, where it had permeated to a distance of 0·1093in.

These changes were easily observed. and were compared by inspection with similar specimens in the author's possession. In order to check up these observations, the author decided to test the strength of the outer fibre of the surfaces of the casting, and compare them with the fibre stresses of samples cut from the same metal, but immediately behind those cut from the surface. The manner these cuts were made are shown in Fig. 1. Pieces Nos. I. and IV. represent the inner surface of the separator, while Nos. I′., IV′., and IV″. are samples cut from immediately behind those, and between them and the centre of the casting. Nos. II. and III. represent the outer surface of the separator, while II′., III′., and III″. are samples cut in a like manner behind these mentioned above.

No data could be found of any tests made and reported showing the relative differences of strength between the fibres forming the scale surface of a casting and parts taken from the inner portion of the same casting. Comparisons are made, therefore, between the fibre strength of the outer surface of the separator (II. and III.) and the strength of the fibre forming the inner surface (I. and IV.). These values were also compared with the results obtained from the various samples cut from the central portions of the casting.

All samples were approximately $5\frac{1}{2}$in. long by $\frac{5}{8}$in. wide, and $\frac{1}{10}$in. thick. The knife-edged supports used for the breaking tests were $4\frac{1}{2}$in. apart, with the load placed at the centre. These samples were broken with the results shown in Table II.

Table II.

Mark.	Breaking Load.			Dimensions.		Maximum Stress on Outer Fibre.
	Lbs.	Oz.	Lbs.	B.	H.	
I.	11	12	11·75	0·638	0·0745	22,400
II.	20	15	20·94	0·641	0·0779	36,300
III.	22	2	22·12	0·646	0·0806	35,600
IV.	36	15	36 94	0·659	0·1162	28,100
I.′	17	11	17 69	0·736	0·0785	26,300
II.′	19	10	19·62	0·643	0·0870	27,200
III.′	16	1	16·06	0·651	0·0784	27,200
III.″	19	5	19·31	0·654	0·0855	27,300
IV.′	34	11	34·69	0·657	0·1107	29,100
IV.″	31	0	31·00	0·655	0·1085	27,100

In order that comparisons may be made easily the results shown in Table II., are rearranged, and averages are shown, from which deductions may be made, in Table III.

Table III.

Marks.	Outside of Casting.	Mean.
II. and III.	36,300, 35,600	35,950
II.′ and III.′	27,200, 27,200	27,200
III.″	27,300	27,300
IV.″	27,100	27,100
I.′ and IV.′	26,300, 29,100	27,700
I. and IV.	22,400, 28,100	25,250
	Inside of separator.	

By comparing samples II. and III., representing the outer surface of the separator with an average strength of 35,950lbs., with the average of I. and IV., the inner surface, of 25,250·3, it will be seen that the fibre strength of the outer surface is about 29 per cent. more than the inner surface. It is safe to assume that a large part of this difference is due to the deterioration of the casting due to its heat treatment. It may be assumed that in making the casting the inner surface coming in contact with the face of the core was cooled more slowly than the outer surface that was cooled by the larger mass of the walls of the mould, and therefore the outer surface may be somewhat stronger. This consideration has been neglected, however, in the consideration of this matter.

The loss of 29 per cent. of the strength of the inner surface of the casting that was affected to a depth of 0·1in. would indicate that the total strength of the casting 1in. thick had been lowered about 2·9 per cent. from the original from this cause.

The author summarises the results of his investigations as follows: (1) That the strength of the outer fibre of the scale surfaces of a casting is greater than those of the metal taken from other portions of a casting. (2) That the temperature encountered in pipe lines using superheated steam is sufficiently high to produce disintegration in a casting, causing it to grow and become correspondingly weak. (3) That grey cast-iron fittings of ordinary mixtures are unfit for use in pipe lines designed for superheated steam.

THE JOINING OF METALS.*

BY ALEX. E. TUCKER, F.I.C.

(*Continued from page 424.*)

Autogenous Fusion. — The second method of joining metals referred to is that of autogenous fusion, or running liquid metal of similar character on to the surfaces to be joined, and in its simplest form is very old. It is illustrated in the case of repairing broken rolls and in lead-burning. It has been a practice for the broken surfaces of rolls to be cut away to give room for the new metal. The whole roll is then heated, and hottest possible metal run into the intervening space, with suitable headers to allow of escaping gases. I have seen very successful jobs made under these circumstances, and the system is obviously applicable to many other cases.

In the wiping of lead joints for water services we have an example of semi-fusion welding, for, as is well known, the metal used, invariably a mixture containing a high percentage of tin (lead 33, and tin 67), is always in the plastic state during the operation. Great skill is shown by the workman who frequently makes his own metal, not only in so adjusting the addition of the tin that he can tell by its appearance whether he is right or wrong, but also in his use of it, because the heat at which he applies it has to be adapted to the work in hand, and judgment must be further exercised in seeing that the successive layers he applies are really melted or crystallised on to the preceding chilled ones without any "cold shutting." This process of wiping a joint looks very simple, but undoubtedly it requires a great deal of experience and observation for its successful practice, and many branches of plumbing in which the various pieces of lead are joined show a very high order of technical and manipulative skill. On the other hand, I am told by good practical men that if they had their choice, there are many cases where they would not wipe the joints. Thus, if a union or cock has to be fixed in a lead pipe, the pipe can be coned or socketed and tinned inside, and if the union or cock to be fixed is also tinned and driven in the pipe, and tinman's solder with extra tin be melted in the annular space with a soldering-iron and finished with a blowpipe, a perfectly satisfactory join results. I think that this is so is obvious, as the bursting strength is clearly greater at such a point than that of the pipe itself. It is also obvious that the bursting strength of most of the wiped joints is unnecessarily greater than that of the pipe on which they are made, and so expensive metal is correspondingly wasted. Two ends of lead pipe may be joined perfectly by fitting one into the other and tinning both surfaces and using solder, as above mentioned. Such joints, however, are not recognised in England by public authorities, though I have often seen them, with variations of detail, on the Continent. Thus I have seen a tinned brass tube inserted in the two ends and the whole soldered up—this makes a very neat and cheap joint.

The application of autogenous welding by acetylene, hydrogen, benzol, petrol, or other hydrocarbon vapour to commercial purposes has extended enormously during the past few years, and constructions and work are now possible by the use of such methods which could not be carried out by any other means; thus repair work of ferrous and non-ferrous metals is now done in every town of importance, and tubes of all sizes are made on a very large scale. For branch pipe construction the process is quite unrivalled. For high-pressure steam pipes the joints after screwing are often welded up, and metal vessels, instead of being made with folded joints, are now made with the blowpipe more cheaply and far more efficiently. Lead-burning forms an excellent practice for acetylene welding, as it is fusion welding in the simplest form. It is usually carried out with hydrogen and air, and if the workman can make a good joint with and without a stick of lead, it is a very easy step for him to advance to making one of aluminium or steel, or any metal. Lead-burning, which at that time seems to have been also known as "autogenous soldering," was first introduced about 1833 by Mr. Mallet, although the invention was also claimed by Prof. Daniel, of King's College, and Mr. Thomas Spencer, of Liverpool, read a paper "On the Theory and Practice of Soldering Metals," before the Liverpool Polytechnic Society in 1840, in which he also claimed the discovery of the process. The advantages of such soldering were at once appreciated, especially for chemical works. The objections to ordinary tinman's solder were the great local action set up by varied metals used; and further, the contraction and expansion of the solder under the influence of heat is different to that of the lead which it joins, and so leaks are much more likely to develop.

Fletcher, of Warrington, was the first to introduce autogenous welding. This was in 1888, but he had no commercial success, partly on account of the low heating power of the oxygen and coal gas which he employed, and, secondly, on account of the poor quality of the oxygen at his disposal. Further, the blowpipe used was very imperfect; there was great difficulty in maintaining a uniformly reducing flame. The first practical success with fusion welding was obtained by the late Felix Jottrand, of the Oxyhydric Company, of Brussels, who also introduced the first commercially successful application of oxygen for the opposite purpose, namely, the cutting of iron with oxygen, a process also previously demonstrated by Fletcher. Jottrand's success was undoubtedly due to the fact that the gas employed by him was made by the electrolysis of water, and so was of high quality, and his blowpipe, though complicated, was very efficient. It is still a disputed point whether under some conditions his method with oxy-hydrogen is not better than oxy-acetylene. In either case it is important that the oxygen used be considerably less than the theoretical amount required, in order that, although only a lower flame temperature is available, the flame will always be reducing in character. Benzol, petrol, and other hydrocarbons have been recently used in place of hydrogen and acetylene for autogenous welding, and their use would, under certain conditions, have advantages.

The Oxy-acetylene Process.—In practice I have found that a proportion of four volumes of acetylene to five of oxygen gives much better results than the theoretical two volumes of acetylene to five of oxygen. So important is this detail that blowpipes are now generally constructed to consistently maintain a reducing flame. Such a blowpipe is that of the Drager-Greishiem. In this blowpipe the automatic reducing valves on the cylinders are fitted with gauges, which instead of being graduated to pressure are marked with the thickness of the material to be welded—all, therefore, that is necessary is for the workman to adjust the springs on both regulators, so that both gases indicate the same thickness. A simple mechanical mixture is arranged on the blowpipe, making the whole apparatus very practical and convenient. A characteristic of the oxy-acetylene flame is that it indicates the correct mixture, for when the acetylene is in excess a small green cap appears over the inner cone of the flame. On reducing the oxygen there is a point at which the cap disappears. The right mixture is just at this point, and the effect is so distinct that when working with acetylene the workman has no excuse for not getting the right proportion.

If temperature were the only consideration, the oxy-acetylene process would be used in all cases in the working of thin metal, but its use requires much greater skill than the lower heat of the oxy-hydrogen flame. Then again, when a fixed acetylene generator is not available, the risk and danger of a portable generator is considerable, and in such cases for oxy-acetylene welding "dissolved" acetylene only should be used. On the other hand, this is very expensive, and the apparatus is heavy, and it therefore follows that the oxy-hydrogen method with its complete portability is very often to be preferred, because hydrogen can be obtained in the usual bottles, and thus forms very convenient plant.

In welding metals other than iron, not only the melting point but the heat conductivity of the metal must be considered. Thus copper with its high conductivity and its low melting point can hardly be worked with the oxy-hydrogen flame. Indeed, for the same section as iron it requires a much more powerful oxy-acetylene flame. Brass, bronze, and, indeed, any metal, may be autogenously welded, and many require much less care than that for aluminium.

The conditions of success which apply to all welding with acetylene or other hydrocarbons are: (1) The use of pure gases; (2) the use of a metal rod of approximately the same composition as that of the work to be joined; (3) the thorough

* Paper read before the Institute of Metals, September, 1912.

fusion of the inside surfaces before the additional metal is applied; (4) cleanliness of the parts, and when desirable the use of suitable dioxidising and fluxing powders, such as charcoal and borax, and lastly, the use of a blowpipe capable of complete control in respect to size of flame and proportion of mixture. With extended experience in the autogenous joining of non-ferrous metals, it is to be expected that this method will replace ordinary brazing where quality of work is of the first importance.

It should be noticed that in consequence of the highly local heating action of acetylene, contraction strains are likely to be set up, which may be more serious than those occasioned when the whole work is heated and welded up in the smith's fire in the ordinary way. In the case of cast iron, it is very desirable that such strains should be avoided by making the weld first and then reheating the mass as much as possible, and cooling slowly. With respect to steel, it has been repeatedly shown that an acetylene or electric weld should not be hammered while the weld is being made. It is well known that cracks are likely to be made by hammering the metal at a black heat, a temperature occurring quite close to the point of fusion. The work, therefore, should be allowed to cool slowly and then raised to a high temperature in the ordinary way, and not by the blowpipe; the weld can in this way be much improved both in shape and strength. A good fusion weld very seldom breaks at the point of welding—indicating, therefore, that this point is stronger than the neighbouring metal. I believe this is the explanation of the paradoxical effect noticed with fusion welding, that thick sections never give as high a tensile strength as thin. I have figures showing this. Thus $\frac{1}{16}$in. 3 per cent. nickel steel strips gave 97 per cent. strength, $\frac{1}{4}$in. gave 90 per cent., while 1in. bars broke at 60 per cent. to 70 per cent., with the fracture clear of the weld every time. Again, welded $\frac{1}{2}$in. copper rods drawn down to $\frac{3}{8}$in. in the ordinary way gave regularly 95 to 97 per cent. as compared with the original drawn rod.

The Use of Aluminium Powder.—There is an interesting series of processes for the autogenous joining of metals, most of which are patented, which depend on the reducing power of aluminium. Anyone who has seen the application of the Goldschmit or Thermit process to the joining of the ends of tram-rails can hardly fail to be struck by its extreme beauty and simplicity. We have here a small steel foundry not much larger than a silk hat, from which the metal pours in a perfectly liquid state. As showing the great heat obtainable when aluminium powder is used for welding, it may be mentioned that if a wrought-iron plate 1in. thick is placed under the crucible, the liquid metal when tapped will burn a hole straight through it, leaving a fairly smooth edge. Experiments show that the heat of the molten metal approaches 3,000° C., the temperature of a Siemens furnace being about 1,600° C.

This Thermit process has been applied for the repair of ship's sternposts and other large fractures, and means have been adopted for heating up the fractured surfaces to the proper temperature before pouring in the cementing iron without damaging the clean metallic surfaces. This is done by building up the moulding-box around the fracture in such a way that it may act as a flue or chimney to an outside fire worked with a compressed air blast, which dries the sand mould and heats up the metal very rapidly. The presence of even a small trace of moisture in the mould gives rise to blowholes in the thermite iron, hence great care must be taken that the mould is as dry as possible. The repair of the sternpost of the German Lloyd steamer "Friedrich der Grosse" was effected in this way. The only doubtful point in the process is the possible formation of internal fractures or cracks, but it is stated that in all the tests of the results fracture has invariably taken place outside the welding region.

It is very probable that in point of strength most thermite welds are superior to those electrically made, because the volume of heat is greater if not more intense, and again, there is less risk of the original surfaces being burnt or oxidised. The thermite metal can also be adjusted to carry reducing media, which would quite eliminate any oxidising influences. Thermite proved useful during the Russo-Japanese War, especially on the Russian side. After the first attack of the Japanese on the Russian fleet at Port Arthur several tons of thermite were forwarded to the Russian Government, and the speedy repairs of many of the Russian ships were due to its use.

Arc Welding and Resistance Welding.—A third system of autogenous welding is the electric, of which two methods are in use, namely, arc welding and resistance welding. Arc welding is applied for repairing breakages and filling up flaws in castings, while resistance welding is rapidly being adopted for the working up of metal articles, and it is common to find electric plant in operation for sheet-iron working. Two forms of machines are on the market for this purpose, one known as the spot-welding machine, and another for butt-welding. In the spot-welding machine the sheets are joined at spots instead of rivets, hence the name. The electrodes are shaped in accordance with the work to be done, and are put on to the work by pressure effected by a foot lever, and the current, which is automatically switched on at low potential, welds the parts together at that point. After removing the foot lever the work can be moved along for welding at a new point.

The entire process is so rapid that an unskilled workman is able to make 1,000 welds per hour on plain sheets, while in the same time an experienced hand could hardly put together a quarter as many rivets. The up-and-down movement of the upper electrode may be performed automatically by means of a motor electrically worked. The electrode then falls and rises at regular adjustable intervals, and the workman only has to move the pieces of work. This machine may also be applied on water-tight welding. In this case the travel of the work takes place slowly, so that the points of welding lie close together, forming an unbroken seam. The edges of the sheets are completely softened, and are pressed together seamlessly. Similarly, when the sheets are not too thick, and irregular-shaped sections do not have to be dealt with, the spot-welding machine makes a very satisfactory weld. Thus wheel rims for cycles and motor-cars can be joined perfectly by its means, while the advantage of this system for welding handles on covers, or for welding rings on cooking utensils, &c., are conspicuous. In the same way half-stampings, such as kettle spouts, make up to a very satisfactory job with seamless welding.

Spot welding is coming into very extensive use for the manufacture of kettles, buckets, and similar articles in which the surface is required to be joined only in parts. In the case of kettles intended for enamelling the old form of riveting occasioned difficulties when the goods were enamelled, because the edges of the rivets and the edges of the sheet refused to take the enamel, or in such thin layers as to interfere with the appearance of the finished work. The difficulty has been avoided and riveting rendered unnecessary by fusing the parts which were formerly riveted by means of the electric arc. The two surfaces are fused together at the point at which the arc is applied and the enamel can then be run on without any difficulty.

Again, in the manufacture of gas stoves, where it is desirous to have a layer of air between two sheets in order to economise heat, spaced depressions are made by means of a blunt punch on the sheets, and the sheets put back to back. On applying the arc to the depressions the apices of the latter are fused together, after which the sheet or sheets are enamelled in the ordinary way. The same process is applied to other goods in order to avoid riveting, and one other advantage is the one of greater permanency in point of mechanical strength, where the goods are alternately heated and cooled. Under this condition of heating and cooling, rivets were often becoming loose, and so occasioned trouble. Galvanised work can be spot-welded. The zinc volatilises off, leaving the iron exposed at the point where the dies come in contact with the metal.

The acting electrodes can be made into various shapes to suit special work. Thus, one can be made circular, freely movable on its axis, while the upper one may be formed of a circular piece of copper swung by a lever. Such electrodes are useful for welding short seams, such as triangular spouts of coffee-pots, &c. As the pressure put upon the material is very high, it will be understood that there is hardly any difference in strength between the welded and the unwelded material.

Compound Sheets.—The manufacture of compound sheets of metal is very old; thus, years ago, capsules for bottles containing liquids intended for domestic purposes were made from a compound sheet of tin and lead. The tin was used to prevent any action of such liquids on the lead—lead being a cheap

and ductile metal which could be easily folded over the vessel, and so made water-tight. Such compound sheets were made by passing a sheet of lead and tin together through hot rolls, when complete union of the two was effected. Another illustration of compound metals is that of French plating—articles such as steel blades or knives, or flat brass surfaces, were plated by placing a sheet of silver on each side of the article to be treated. The whole was then bound with wire and heated in a muffle or other suitable furnace until a union at points was effected, after which the surfaces were burnished to improve the union, the whole being kept hot. Such goods were not, however, very permanent, and in the case of iron and steel work this might be expected, on account of oxidation. In Sheffield plate, which is also made in Birmingham, such plating is done exclusively on copper or its alloys. An ingot of such metal free from defects is well cleaned and coated with a saturated solution of borax. A sheet of silver is then laid on one or both sides of the ingot, according to whether the work is for single or double plating. The amount of silver used is considerable—thus for single plating it varies from $\frac{1}{24}$ to $\frac{1}{30}$ of the total weight, while for double plating this proportion is preserved in the double plating—*i.e.*, the sheets of silver are half the gauge. After adapting the silver, the surfaces are brushed over with a saturated solution of borax, and the work bound together with wire. It is then heated in a furnace till the borax begins to run. The heat is carefully watched to prevent the silver running completely into the ingot. The point at which the work should be drawn is that at which the silver is drawn down flat on the surface. The operation is complete when a layer of solder is formed between the silver and copper, hence the care required in watching the heat. After removal from the furnace the work may be rolled to any desired thickness if properly annealed between the passes. After annealing, the metal may be treated as a homogeneous material, and may be raised, spun, stamped, or otherwise worked. Tubes or wire of Sheffield plate are produced as follows. A strip of silver is formed into a rough tube with an overlap; a red-hot copper mandrel is then inserted into this, and the overlapping edges of the silver are made to adhere by hammering and burnishing. This tube is then cleaned inside, and a sliding fit made of it over a copper rod covered with borax; the ends of this rod are roughly grooved in order to engage the sheet of silver better, and also to exclude the air. The whole is then heated to redness and burnished down, after which it is passed through dies or beading machines, as required.

The last system of joining metals to which I desire to direct attention is the one in which the surfaces are not melted, but only slightly heated. During recent years the manufacture of compound metals, such as nickel and steel, copper and steel, aluminium and copper, has become of great practical importance, and many beautiful articles are now sold for domestic purposes. The nickel steel, copper steel, or nickelled zinc sheets may be obviously produced electrolytically, and afterwards rolled down to gauge, allowance being of course made for the ductility of the softer metal. But another method has lately been introduced in which sheets of different metals may be joined perfectly.

The manufacture of aluminium-copper sheets illustrates the process, and further is interesting from a metallurgical standpoint. One method with which I am familiar is as follows. The copper sheet is pickled and cleaned. Aluminium powder is then brushed on by machinery, or by rubbing the surfaces with brushes or rollers of aluminium wire. A sheet of cleaned aluminium is then placed on such a surface, the two are heated and passed through rolls. The union is perfect, and hence the compound sheet may be subjected to stamping, spinning, &c., without any trace of lamination. In the same way copper and steel, or almost any two or any number of sheets of different metals, may be compounded. The aluminium acts as a metallic adhesive. While rolling such sheets the top surfaces are often kept oiled to retard oxidation, and to obtain better finish.

In view of these results, it would appear probable that the method could be modified in such a way as to produce ornamental designs by similar methods as those employed in the inlaying of wood already described, with the difference that two sheets would be employed and not three, on account of the impossibility of splitting the ornamental sheet, as is done with wood. Further, although I have not seen it done, it becomes possible by slight modification of the process to produce a design having several differently-coloured metals, thus giving effects similar to those produced by parcel gilding or plating.

A second method of making a compound sheet of different metals is that in which an oxide or sulphide of a metal which will alloy with both of the two sheets is taken and mixed with aluminium powder, and the mixture laid evenly between them. The whole is then heated to the fluxing point of the mixture and then rolled, and as the two sheets to be joined receive the full heat of the furnace in which the work is placed, it will be understood that the alloying of the metal from the mixture with the two surfaces of the sheets is very complete.

In another method, where still more heat is used, for the production of compound plate, say, of aluminium and copper, copper or other wire gauze is placed between the sheets, and the interstices filled as before with aluminium powder and flux, consisting of alkaline, chloride, and fluoride. On heating the whole and rolling, the surfaces unite as before described, and probably more perfectly, because the gauze retains the flux better during the heating, and so does its work better, and is afterwards squeezed out by the rolls, while in addition there would also be the knitting or dowelling action of the gauze during rolling, which would further tend to hold the sheets together. The use of such wire gauze would seem to be applicable to certain conditions of brazing, especially when the greatest care is necessary to produce the highest quality of work, such, for instance, as the brazing of steam pipes to which allusion has already been made.

STANDARD METHODS OF SAMPLING FOR CHECK ANALYSIS OF STEEL.

The Association of American Steel Manufacturers has just adopted a set of rules to be followed in obtaining samples for the check analysis of steel. This latest activity of the association is in response to the need that all manufacturers and many consumers have felt for uniform conditions which should govern both parties when steel is to be analysed, especially when its acceptance or rejection depend upon check analysis. A booklet entitled "Standard Methods of Sampling for Check Analysis," containing the new rules, is issued under the new classification of "Manufacturers' Standard Practice," which the association now uses for certain of its adopted rules, when they are not strictly of the nature of specifications. The introduction and the description of the methods are as follows: It is a recognised fact that the different parts of a piece of steel are liable to vary in composition. This variation occurs principally between the centre and the outside, and to a slighter extent is dependent upon the position of the piece in the ingot, and the size of the ingot. Where a sufficient number of check analyses have been made from drillings properly taken at different points in the heat to represent it fairly, their average has been found to compare favourably with the ladle analysis, which is the analysis of a small test ingot taken at any time during the pouring of the heat. From this it is evident: (1) That the ladle analysis is more representative of the composition than any single analysis of the finished material. (2) That drillings for check analysis, to be fairly representative, should be taken at a point intermediate between the outside and the centre of the cross-section. (3) That a sufficient number of check analyses of different pieces should be made to afford a fair average to compare with the ladle analysis.

Points to be Observed in the Sampling of Material for Check Analysis.—(*a*) Each heat in a lot shall be considered separately, and pieces for sampling shall be taken to represent the heat as fairly as possible.

(*b*) Samples must be drillings or chips cut by some machine tool without the application of water, oil, or other lubricant, and shall be free from scale, grease, dirt, or other foreign substance. If samples are taken by drilling, the size of the drill shall be not less than $\frac{1}{2}$in. nor more than $\frac{3}{4}$in. diam.

(*c*) Samples must be uniformly fine and each must be carefully mixed before analysis.

(*d*) In referring samples to the manufacturer or other analysts for check analysis, a piece of the full-size section, when possible, should be submitted rather than cuttings, unless the latter are specially requested.

(e) Where material has been subjected to heat treatment other than annealing or simple cooling, subsequent to its manufacture, it should be annealed before sampling.

(f) Check analyses are not representative of the original material when its composition has been altered in any way by some operation, such as case-hardening, overheating, &c.

Methods of Obtaining Samples for Check Analysis.—Material has been divided into the following classes, depending upon the manner of sampling:—

I. Material subject to physical requirements:

Samples for check analysis shall be taken from a test specimen. Where it is required to make additional check analyses, samples shall be taken as indicated under II.

II. Material not subject to physical requirements:

(a) Special cast, rolled or forged, semi-finishing or finished material of large size, such as ingots, blooms, billets, slabs, rounds, shapes, &c., subject to acceptance on check analysis.

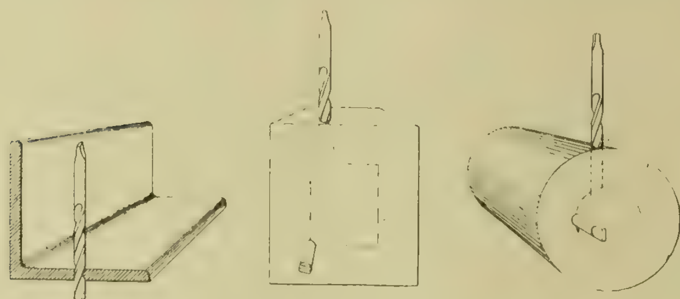


Fig. 1.

Samples shall be taken at any point midway between the outside and the centre by drilling parallel to the axis. In cases where this method is not practicable, a piece may be drilled on the side, but drillings shall not be taken until they represent the portion midway between the outside and the centre. (See Fig. 1.)

(b) Small or thin material, such as plates, shapes, bars, &c., subject to acceptance on check analysis.

Material for which the previous method is not applicable shall have samples for analysis taken entirely through the material at a point midway between the outside and the centre, or by machining off the entire cross-section.

(c) Commercial material subject to acceptance on ladle analysis.

The methods described under II (a) and (b) shall apply, except that samples shall be taken at any point one-third of the distance from the outside to the centre.

Methods of Analysis.—Analyses shall be made by well-known accurate methods. Carbon shall be determined by the combustion method.

Rejection of Material on Check Analysis.—Any rejection of material ordered to a specific chemical range shall be based on the following:—

(a) The minimum number of samples to be taken from a heat before rejection by the purchaser shall be as follows:—

Weight in gross tons.	Minimum Number of Samples.
5 or less	3
10 or less, but over 5	4
15 or less but over 10	5
Over 15	6

In case the number of pieces in a heat is less than the number of samples given, one sample from each piece shall be considered sufficient.

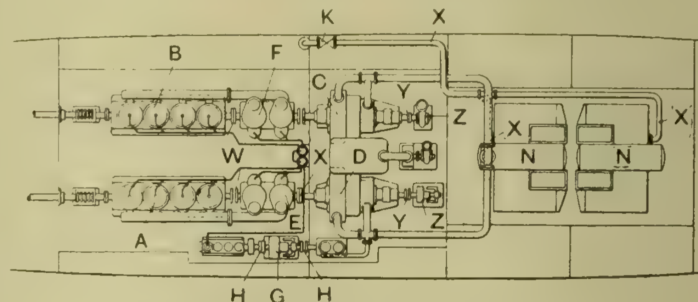
(b) Separate determinations shall be made on each sample and the results averaged, unless they clearly indicate mixed grades.

ARRANGEMENT OF ENGINES FOR SHIP PROPULSION.

An arrangement of the propelling engines for ships in which both steam turbines and continuous combustion internal-combustion engines are provided has recently been patented by Messrs. Sulzer Bros., Winterthur. This arrangement enables the fuel to be employed which is most readily obtainable at the various ports of call. For instance, it is impossible in many places to obtain sufficient crude oil for working Diesel engines, more particularly when there are no tanks, &c., and coal is at times so scarce or expensive that its price plays an important part in determining the kind of fuel which it is best to use at any particular place. Moreover, the kind of cargo, the risk of fire, or other factors may also influence the choice of a suitable fuel.

The arrangement is shown in plan in the accompanying illustration. Two Diesel engines A and B, and two steam turbines C and D are provided. The shaft of each steam turbine is arranged co-axial with that of the corresponding Diesel engine, and between each steam turbine and Diesel engine in axial alignment therewith is arranged a pump E or F. These pumps supply scavenging and charging air, as well as compressed air for starting, reversing, atomising, and injecting the fuel. The Diesel engines A and B comprise working cylinders only and are not directly connected with their pumps. The adjacent ends of the shafts of the internal-combustion engine, air pump, and steam turbine are provided with couplings or clutches W, X, so that various connections can be obtained by coupling or uncoupling these shafts. For instance, if the Diesel engines are required to transmit their greatest power to the propellers, the clutches W are uncoupled and the clutches X engaged so that the turbines drive the pumps F, E, or only one of these pumps may be so driven. Again, even if the couplings are in engagement the combustion engine or the auxiliary air pump or the steam turbine may run idly.

As shown an auxiliary machine Z, such as a pump or dynamo, may be connected to the free end of the propeller shaft Y, and another special arrangement of auxiliary machines such as may be used in mixed working is also shown. On ships auxiliary engines are required for such purposes as bilge pumps, lighting, steering gear, hoisting apparatus and the like. In the present construction such auxiliary machines G, for instance, dynamos, pumps, &c., are provided on both



Arrangement of Engines for Ship Propulsion.

sides with couplings H. To drive these auxiliary machines either by an internal-combustion engine or by a turbine or other steam engine, one coupling of the auxiliary engine can be connected to the steam engine, or the internal-combustion engine may be connected to the other coupling. In that way, these auxiliary machines can be driven either only by means of the combustion engine, or only by steam, or jointly by both kinds of engines. The entire steam installation, and independently thereof, the internal-combustion engine installation is each arranged in a water-tight compartment. For making the coupling possible, the shaft ends are carried through stuffing-boxes formed in the water-tight partitions.

It is not always absolutely necessary to fire the boilers only with coal, though they would normally be worked with the fuel which is the cheapest for the purpose. In some cases, however, an accident may render the Diesel engines useless, or the internal-combustion engines may prove insufficient to propel the ships, whilst there is on board only fuel for working the Diesel engines. It will therefore be necessary to start the steam engine, and where there is no coal, as in the above-mentioned case, or where the price of coal is excessive, it may be found advantageous for the purposes of economy to fire the boiler with the same fuel as that used for the internal-combustion engine. The illustration shows a valve or cock K which, in the case of the boilers being fired with the liquid fuel primarily intended for the internal-combustion engine, is opened to allow the liquid fuel to pass through the pipe X to the boiler N.

IMPROVING THE SOUNDNESS OF STEEL INGOTS BY THE AID OF THERMIT.*

BY DR. HANS GOLDSCHMIDT.

It is well known that all alloys in transition from the liquid to the solid state tend to lose their homogeneity. The constituents which in the liquid state were uniformly distributed begin to segregate on solidifying, with the result that ultimately the ingot, when cold, is no longer homogeneous, and has not the desired composition in all parts. The attainment of homogeneity in the preparation of alloys is a matter that has consistently engaged the attention of metallurgists.

Steel, that is, material made by a fusion process, must be regarded as an alloy of iron with several elements, more particularly carbon, manganese, and silicon; phosphorus, sulphur, and copper being also present as impurities. The purer the iron the higher its melting point, and the other constituents of the alloy, especially carbon, and also phosphorus and sulphur, have the effect of lowering the melting point. In the production of steel, therefore, the purest constituents, that is, those which have the highest melting point, are the first to solidify and settle at the bottom and sides of the ingot mould. At the centre and head of the ingot, on the other hand, where the metal remains longest fluid, are gathered the more readily fusible impure elements which have separated out during cooling. The principal elements which accumulate near the top in this way are sulphur and phosphorus, &c., which exercise so injurious an influence on the mechanical properties of the material.

The serviceableness of an ingot is not only reduced by the process of segregation, but by a whole series of other defects arising during cooling and freezing. For instance, during the transition from the liquid to the solid condition the volume of the ingot undergoes a change due to shrinkage. As solidification progresses from the sides and bottom inwards and upwards, the neighbouring layers of liquid and semi-liquid material are attracted, owing to the gradual diminution of the volume, until finally, in the centre of the ingot and towards the end, a large hollow, known as the pipe, is formed, which is the distinctive and objectionable defect of almost all steel ingots.

This, however, by no means exhausts the list of defects arising during the cooling and solidifying of an ingot. The material undergoes further change, owing to the evolution of gases shortly before freezing in the case of metal to which no silicon addition is made either in the furnace or ladle, that is, material which has not been siliconised, and at the same time contains only a low percentage of carbon. The evolution of gas is very energetic, and is accompanied by vigorous sparking. The gases consist of hydrogen and carbon monoxide, and as long as the metal in the interior of the ingot is sufficiently fluid they can escape freely and rapidly. But as cooling proceeds they become entangled and form blowholes of various dimensions within the ingot. These gas enclosures also adversely affect the homogeneity of the ingots, and frequently they exercise a most injurious effect on the quality of the material, when they attain a considerable volume, owing to their inability to work their way upwards through the already solidified metal. By careful working these defects in the ingot can be kept within comparatively reasonable bounds, and it is not the object of this paper to describe exactly the remedies usually resorted to. Mention may, however, here be made of a very valuable investigation by Dr. Canaris upon the influence of pouring upon the quality of mild steel blooms.† Dr. Canaris, who is the manager of the rolling mills of Messrs. Schulz-Knaudt, Aktien Gesellschaft, at Angerort, near Duisburg, has exhaustively described the many precautions which are generally taken in order to obviate as far as possible the above enumerated defects arising during the freezing of a mild steel ingot.

The question of the prevention of piping in ingots is one that has always occupied the attention of metallurgists, and, among other remedies, the use of thermit was long ago recommended. The method of its application was to break open the crust which formed at the top of the metal in the mould, and to plunge a cartridge filled with thermit into the pipe, in order to remelt the surrounding parts. As soon as this remelting was effected, the hole was filled by pouring in fresh liquid steel from the ladle. The process, as thus carried out, was, therefore, a purely thermal one. Unfortunately the method did not yield the desired results, in spite of the numerous trials made at a great many steelworks. In fact, it was only in exceptional cases that success was obtained, so that it was no wonder that this so-called anti-piping thermit process was soon discredited and forgotten.

Latterly, however, a new and very successful improvement of that old process has been made, which has proved very efficacious, especially in the treatment of non-siliconised steel, that is, steel to which no silicon addition has been made either in the furnace or in the ladle. At first sight it might be thought that the method had been altered only in one small detail, for the apparatus, consisting of a sheet metal cartridge filled with thermit, has been retained. It differs totally, however, in the mode of application and the result achieved.

Whereas formerly the thermit cartridge was used solely for the purpose of melting the upper portion of the ingot containing the pipe, the lower end having already solidified, the cartridge, according to the new method, is quickly plunged

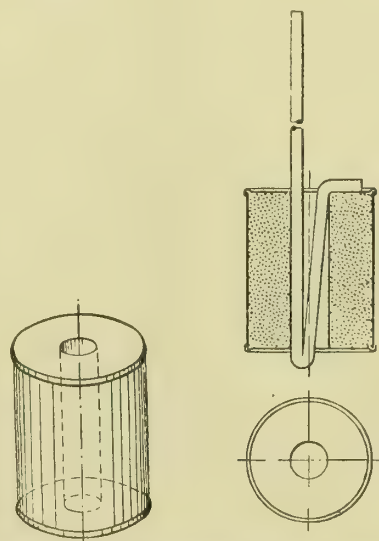


FIG. 1.—SHOWING THERMIT CARTRIDGE AND ROD FOR PUSHING TO THE BOTTOM OF THE INGOT.

right to the bottom of the ingot before solidification has begun to set in, that is, before any of the defects referred to have had time to take effect. The reaction immediately causes an energetic ebullition of the liquid contents of the ingot mould, and the gases which have just begun to separate out are violently expelled, or, if the charge has not been siliconised, the bubbling of the metal due to the disengagement of the gas is incidentally checked. But the most noticeable feature is the sinking down of the liquid metal in the mould by more than a hand's-breadth as soon as the reaction is complete, and the density of the material is increased by an amount corresponding to this reduction of volume. Further metal is then poured in from the ladle, until the level of the ingot is restored, and the ingot, if of non-siliconised steel, is then covered with an iron plate in the usual way. The violent frothing up, due to the reaction of thermit, has other good effects, for the segregation already accumulating in the centre is driven upwards and the further formation of segregates prevented.

The new method has proved particularly effective for the treatment of ingots intended for rolling into plates, and the advantages here are very apparent. In this connection the new process was first tried at a steelworks combined with a plate-rolling mill, namely, the German firm of Schulz-Knaudt, A.G., and it was due to the enterprise of the steelworks manager, Dr. Canaris, assisted by Mr. Biewend, Engineer of Messrs. Th. Goldschmidt, A.G., of Essen, that the process was first put into practical operation. The author's thanks are due to both these gentlemen for their care, which resulted in bringing the matter to a successful issue.

* Paper read before the Iron and Steel Institute, September, 1912

† C. Canaris, "Doctor's Dissertation on the Influence of Pouring on the Quality of Mild Steel Blooms." Dusseldorf, *Stahleisen*, m.b.H.

Referring now to the results obtained with plates rolled from slabs treated with thermit in this manner, during the trial of the thermit process at those steelworks more than 4,000 ingots, varying from 1 to 8 tons in weight, were treated as described, and exact records were kept of the working results.* It was found that the number of plates rejected, owing to the faultiness of the ingot, amounted only to 0·3 per cent. of the total weight of the ingots, whereas in many works the percentage of rejection amounts, as is well known, to 15 per cent. or more. That figure of 0·3 per cent. could have been still further reduced if the defects due to rolling alone had been also taken into account.

In order to appreciate this result at its true value, the following circumstance must also be taken into consideration. In view of the fact that the quality of the ingots was improved in every respect, and that a much greater regularity in working was ensured, it was soon found possible, keeping the plates the same weight as before, to reduce the weight of all the ingots by 5 per cent., that is, to make them 5 per cent. less weight than is required in general practice. The principal advantage is that due to economy in rejections, but whereas this saving cannot very easily be calculated in exact figures, the advantage due to the 5 per cent. reduction in the weight of the ingot can be accurately computed. Assuming that the rough finished plates are worth £6 a ton, and that scrap costs £3 a ton, the difference in value of the raw material and the finished product is £3 per ton, or 60s., that is to say, the 5 per cent. reduction in weight represents a saving of $\frac{5 \times 60}{100} = 3$s., since the cost of the thermit process, under the least favourable conditions, that is, if only small ingots are cast, does not exceed 1s. 6d. per ton, a net saving of at least 1s. 6d. per ton of plates rolled results. In the case of large ingots the economy is considerably greater, for the reason that the cost of the thermit treatment is then reduced to one-half or even less. The proportion of wages and consumption of rod iron is the same for a large as for a small ingot, while the quantity of thermit used is relatively smaller per unit of metal.

Further advantages are that the quality of the plates produced is much improved, and, in particular, the strength in different parts of the plate is much more uniform, this being due to the prevention of segregation. Added to this, there is also the capability of increasing the output without injuring the plant, and the quantity of waste is much reduced. The working of the rolling mill proceeds with greater regularity, owing to the reduction of the number of wasters to a minimum. Therefore, no interruptions need occur in the execution of orders. Dr. Canaris pronounces the process to be an ideal means for the improvement of the quality of the ingots.

Another important point may be specially mentioned, namely, that for the carrying out of the process no special apparatus is necessary, and no cost is incurred for the instalment of such apparatus. All that is required is the sheet iron box with thermit of the proper capacity, and an iron rod, by the aid of which the box is thrust down into the molten metal.

There are a number of other well-known processes which have for their object the prevention of pipe and the production of sound and homogeneous ingots. Some of these aim at keeping the head of the ingot liquid, but these are not applicable in cases where non-siliconised steel is being worked. For such metal a method of mechanical compression such as the Harmet process is the only other one that is in the least serviceable, by which, as is well known, the pipe and blowholes are eliminated by compression, but, in contrast to the thermit process, the application of fluid compression entails much and very costly plant. Moreover, with the Harmet process, only a limited number of ingots can be treated simultaneously, and the operation occupies several hours.

The author, however, has no intention of comparing the various processes, and although it would be acknowledged that the thermit process has various other advantages over the Harmet, he would only emphasize one, which consists in the greater simplicity and consequently a much greater cheapness of the thermit process. The results of Dr. Canaris' experiments, described in his report referred to above, together with analyses, particulars of tensile tests, and yield of finished plates, are given in the following tables. In Table II. the doubling length and the mechanical properties of the thermit plates are compared with those of plates which have not been treated with thermit.

TABLE I.—*Analyses and Tensile Tests of Thermit-treated Plates.*

Plate No.	Analyses.								Corresponding Tensile Tests.			
	Head.				Foot.				Head.		Foot.	
	C per cent.	Mn per cent.	P per cent.	S per cent.	C per cent.	Mn per cent.	P per cent.	S per cent.	Tensile Strength Kg/m.²	Elongation per cent.	Tensile Strength. Kg/mm.²	Elongation per cent.
1	0·082	0·40	0·022	0·040	0·078	0·40	0·019	0·038	37·9	28·0	36·2	30·5
2	0·072	0·49	0·048	0·046	0·070	0·48	0·033	0·040	37·7	29·5	36·2	32·0
3	0·076	0·45	0·028	0·020	0·070	0·43	0·026	0·018	38·2	27·5	36·0	31·5
4	0·071	0·47	0·040	0·030	0·069	0·45	0·032	0·026	36·8	28·5	35·1	32·0
5	0·082	0·45	0·028	0·020	0·074	0·43	0·026	0·018	38·6	26·5	36·1	31·0

TABLE II.—*Results of Tests of Ingots Treated with Thermit.*

Remarks.	Plate No.	Weight of Ingot, Kgs.	Width of Plate. Millimetres.	Thickness of Plate. Millimetres.	Doubling Length. Millimetres.	Tensile Strength. Kg/mm.²	Elongation per cent.	Locality of Test-pieces.
With thermit	1	1285	2355	11	160	36·8	32·0	Foot
						38·7	28·5	Head
„ „	2	1295	2100	10	120	36·6	30·0	Foot
						37·8	28·0	Head
„ „	3	1295	2355	11	120	36·1	32·0	Foot
						38·2	29·5	Head
„ „	4	1290	2355	11	120	36·4	31·0	Foot
						38·1	29·5	Head
Without thermit	5	1245	2115	10	770	36·8	28·0	Foot
						41·9	20·0	Head

TABLE III.—*Showing Sizes of the Thermit Boxes or Cartridge prepared for Ingots of Different Weights.*

Mark Indicating Class of Box.	Contents. Kilogrammes.	Weight of Ingot. Tons.
00	0·65	1—1·7
0	1·3	1·7—3·5
I	2·5	3·5—8·0

* From November 1st, 1911, till July 31st of this year 17,891 ingots were treated in the above-named steelworks. The ingots varied from 1 to 11 tons, and emanated from 1,436 different heats.

The exact method of carrying out the process on ingots of non-siliconised material is as follows: The filling of the ingot mould is effected in the usual way, either by direct pouring into each mould from above, or filling a number of moulds simultaneously by bottom-pouring. After filling, the moulds are left undisturbed until the crust, which starts from the sides of the mould, has spread some little way inwards. This crust gives an indication of the progress of cooling, and hence of the right moment at which to introduce the thermit cartridges. The width which the crust should be allowed to attain depends, of course, upon the size of the ingot, and is a matter that can only be judged by experience. The thermit cartridge (Fig. 1) is preheated, and by means of the rod shown is thrust vertically down to the bottom of the ingot mould, and is held there till the reaction is complete, the rod being then withdrawn. A scrap-iron rod will serve the purpose, and should be about ½in. diam., or somewhat stouter for the larger boxes. To economise material the bar can be made so that either end can be used. If the operation is performed at the right moment the surface of the ingot sinks down at once by several inches or more directly the boiling ceases. More metal is then poured in at the top, until the surface is again restored to the original level, where the crust first began to form, and an iron plate is then lightly placed on the metal in the usual way and then covered up with sand.

The amount by which the molten metal sinks down differs in different ingots, even in those cast from the same heat. It depends upon the degree of piping or on the size of blowholes which may be forming within the metal. The density of the ingot is, of course, greater by the amount that the metal sinks down. Up to the present experience shows that, by the new method, a much greater homogeneity of ingot can be reckoned upon, using an unprecedentedly simple means. The process is actually nothing less than a stirring-up process, that is to say, a purely mechanical and not a thermal one. Since the weight of thermit required for a 1-ton ingot is only a little over 1lb., the rise of temperature is practically nil. At the bottom of the liquid metal, within a limited region only, an increase in temperature occurs, causing an energetic agitation of the highly-heated particles, by means of which a current is produced. Further, the operation is under very easy control, and the necessary skill in the performance of it is soon learnt. Moreover, the men are not exposed to any risk in carrying it out.

The process has, in consequence, already been adopted at various works with success, and on a large scale. Until the results of the trials at the Schulz-Knaudt works were able to be published, the introduction of it in other works abroad had to be deferred, but there is little doubt that this new method of making homogeneous ingots will soon make headway in other countries. The certainty of being able to produce sound ingots with a very small proportion of discard, makes it probable that in future ingots of large size only will be cast, from which small-size plates will be rolled. The waste due to trimming and cutting up will be inconsiderable. Up till now it has been inadvisable to make large ingots, on account of the large percentage of discard and the resulting disproportionate waste of material. The increase of density and the improvement in quality of the steel are also to be reckoned as economies, and it is by no means unlikely that the thermit process may lead to modifications in rolling-mill practice generally.

Boiler Explosion at Manvers Main Colliery.—The formal investigation ordered by the Board of Trade to be held in regard to the boiler explosion at Manvers Main Colliery, Wath-upon-Dearne, is fixed for hearing in the Council Chamber, Town Hall, Howard Street, Rotherham, on Tuesday, the 22nd inst., at 11 a.m.

EFFECT OF TEMPERATURE ON TENSILE TESTS OF METALS.*

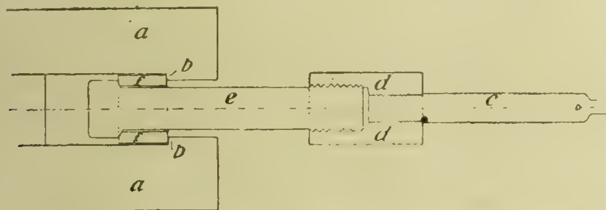
The Effect of Temperatures Higher than Atmospheric on Tensile Tests of Copper and its Alloys, and a Comparison with Wrought Iron and Steel.

BY PROF. A. K. HUNTINGTON, A.R.S.M., F.I.C.

THE tests included in this paper were made at various times between 1900 and the present year. As the method of heating the bars to the required temperature is believed to be different to any method hitherto described, and as it has been proved to be easy to carry out and to give reliable results, a detailed description of it may prove of interest and practical value. One point which has been found of considerable importance in this method of testing is, that the elastic limit or the yield point can be taken, which is not the case when a heated bath or an electrically-heated jacket is used.

As a result of having to consider generally only cold tests of iron and steel, engineers are in the habit of reckoning the elastic limit as 50 per cent. of the breaking load. It will be seen from the curves given in this paper that this method of estimating the elastic limit is not correct for iron and steel at temperatures above the normal, nor, as a rule, for other metals at any temperature.

Method by which the Tensile Tests at Temperatures higher than the Normal were made.—The tests were made with a horizontal machine of the Kirkaldy type. This machine is provided with a saddle, which can be moved along the bed of the machine by handwheel or hydraulic pump. Attached respectively to the saddle and to the levers actuating the beam are two massive heads a, Fig. 1, in each of which there is a vertical slot, the slot being enlarged towards its inner end so as to form two vertical shoulders facing inwards, b. The test-bar c is screwed at each end into a cylindrical holder d, the other end of which is screwed on to the end of a large bolt e, which passes loosely through a hole in a rectangular block f. These blocks fit loosely in the enlarged ends of the slots in the heads. When testing at high temperatures sheet asbestos may be inserted between the blocks and the heads.



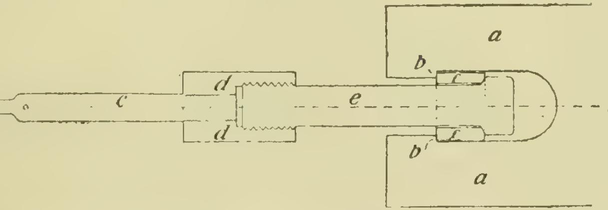


FIG. 1.—PLAN (SECTION) OF HEADS AND HOLDERS ON TESTING MACHINE, SHOWING METHOD OF ATTACHMENT TO BAR.

The test-bars are of two patterns—(a) for use with high-temperature thermometers, (b) for use with a thermo-electric couple. The pattern (a) is 18in. long and 1in. diam., except at the middle, which is turned down to 0·5in. diam. over a length of 2in. The ends are screwed for about 2in. to fit the cylindrical holders, and at 0·5in. from each shoulder a hole is bored centrally (Fig. 2), $\frac{5}{16}$in. diam. and 0·75in. deep, to hold a thermometer. In order that the thermometer may be sufficiently enveloped by the bar, the drill is driven in until the point bulges the metal at the opposite side of the bar. Connection between the thermometer bulbs and the test-bar is ensured by means of a small quantity of a low melting-point alloy. The pattern (b) is 5in. to 6in. long and 1in. diam., the middle being turned down to 0·8in. over a length of 2in. About 1in. at each end is screwed to fit the cylindrical holders.

In order to attach the thermo-couple to the bar, a piece of asbestos sheeting, 1in. long and ½in. wide, is split down a little more than half-way, and a small hole made through one side about the middle. The junction of the couple is inserted through the hole from the inside, Fig. 3 (a), so that the small knob is just protruding on the outside. The asbestos and couple are placed on the bar with the junction of the couple touching the middle of the bar, and bound firmly into position by two or three pieces of thin wire, Fig. 3 (b). The curves, more particularly for electrolytic copper,

* Paper read before the Institute of Metals, September, 1912.

copper-tin, and copper-aluminium, show that very good results can be obtained with high-temperature thermometers, but it is a saving of time to use an electrical pyrometer, which has also the important advantage of enabling bars of a larger diameter to be tested.

The bar is heated by placing a Bunsen burner under each end of the bar with pattern (*a*), and by means of a "bar burner" with pattern (*b*). The burner is 14in. long, and made by Messrs. Fletcher, Russell, & Co., the part under the test-bar itself being prevented from lighting by placing two overlapping pieces of sheet iron over the holes, so that only the cylindrical holders are actually heated by the flame.

Before placing the bar in the machine it has to be marked. A dark streak, about ⅜in. wide, of some suitable ink, is made on the central portion of the bar from shoulder to shoulder. When dry, a small mark is made near one shoulder with a fine centre-punch, and with this mark as centre and a 2in. radius, an arc is scratched across the other end of the ink streak, using spring dividers which have been sharpened. Another punch mark is made on the middle of the arc, and a similar arc made at the first end of the bar, using the second punch mark as centre.

When the bar has reached the required temperature, and this is quite steady, the length between the left-hand centre punch mark and the corresponding arc is measured by placing one point of the dividers in the hole, and laying the other point on the arc and viewing the arc through a hand lens. A suitable load is then placed on the bar, and the bar measured with the load on. If no stretch is observed, the load is slowly increased until a distinct stretch is observed, when the load is taken off and the bar measured. If no stretch is observed with the load off, the load is slightly increased, and the bar again measured with the load off, this procedure being repeated until the bar shows a permanent stretch. The load required to produce this is taken as the yield point. It is found that a stretch of ·003in. can be observed by this method. After the yield point is reached, the load is increased slightly and the bar measured with the load off. If the previous load was really the yield point, an increased stretch will be observed out of all proportion to the extra load applied. If this observation is satisfactory, the bar is "broken out," the load being increased rapidly until the bar breaks, no intermediate measurements usually being taken. With test-bars of pattern (*a*) the thermometers are removed before "breaking out" the bar.

Tabulated Results of Tensile Tests at Temperatures higher than the Normal.—The metals and alloys used in the following tests were specially free from impurities and were annealed. A "trace" in all the analyses means less than 0·005 per cent.

TABLE I.—*Electrolytic Copper, March 13th, 1906. Rolled 1in. Rod.*

Analysis.

Arsenic	trace.
Antimony	nil.
Bismuth	0·0005 per cent.
Selenium	trace.
Tellurium	trace.

TENSILE TESTS.
All test-bars annealed 2 hours at 600° C.

Temperature of Test. Deg. Fah.	Temperature of Test. Deg. C.	Yield Point. Tons per Square Inch.	Breaking Load. Tons per Square Inch.	Elongation per Cent. on 2 Inches.	Reduction of Area per Cent.
55	13	2·86	13·97	56·0	66·3
200	93	2·58	12·41	56·0	68·6
300	148	2·64	11·46	55·0	67·44
400	204	2·85	10·55	53·0	66·3
450	232	2·29	9·61	49·5	61·5
650	343	2·30	6·91	25·0	28·2
750	399	2·33	6·42	27·0	27·16
850	455	1·71	5·43	21·0	26·0
900	482	1·42	5·13	20·5	29·4
900	482	2·00	5·17	23·5	25·1
950	510	1·43	4·17	23·0	26.0
1000	538	0·5	3·7	32·0	45·2

The foregoing results are shown graphically in the curves on pages 467 and 468. It will be convenient to take the electrolytic copper as a standard of comparison, and first of all to compare the copper alloys with it. Broadly speaking,

TABLE II.—*Arsenical Copper, December 21st, 1900. Rolled 1in. Rod.*

Analysis.

	Per Cent.
Arsenic	0·234
Antimony	nil
Bismuth	0·009
Selenium and tellurium	trace

TENSILE TESTS.

All test-bars annealed 2 hours at 600° C.

Temperature of Test. Deg. Fah.	Temperature of Test. Deg. C.	Yield Point. Tons per Square Inch.	Breaking Load. Tons per Square Inch.	Elongation per Cent. on 2 Inches.	Reduction of Area per Cent.
100	37·7	2·27	13·75	50·5	64·0
200	93·3	2 27	12·95	57 5	70 8
300	150·0	2·27	11·81	51·5	70 8
400	204·0	1 98	11·07	49 0	78 8
500	260·0	1·98	9·71	50 0	66·3
600	316 0	1·98	9·32	47 5	58 5
700	371·0	1·98	7·52	16 0	26·0
800	427 0	1·70	5·37	10 0	15·3

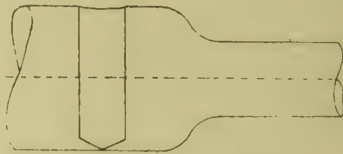


FIG. 2.—SECTION OF TEST BAR ABOUT SHOULDER, SHOWING THERMOMETER HOLE.

TABLE III. *Copper-Tin, February 9th, 1900. Rolled 1in. Rod.*

Analysis.

	Per Cent.
Copper	97·673
Tin	2·408
Lead	0·024
Nickel	trace.
Iron	trace.
Manganese	nil.

TENSILE TESTS.

Temperature of Test. Deg. Fah.	Temperature of Test. Deg. C.	Yield Point. Tons per Square Inch.	Breaking Load. Tons per Square Inch.	Elongation per Cent. on 2 Inches.	Reduction of Area per Cent.
60	15·5	4·83	19·13	56·0	75.0
400	204·0	2·84	16·77	53·0	68·6
500	260·0	2·84	16·25	45·0	56·4
600	316·0	2·84	14·54	23·5	26·0
700	371·0	2·55	11·36	21·0	22·5
800	427·0	3·12	12·97	36·5	29·4
870	465·0	2·84	12·31	38·5	42·2

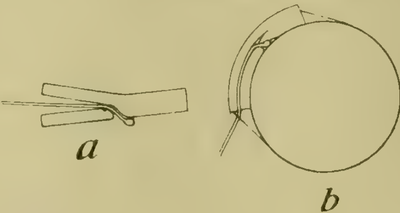


FIG. 3.—SHOWING METHOD OF ATTACHMENT OF WIRES OF THERMO-COUPLE TO BAR.
(*a*) Couple inserted into prepared asbestos sheet.
(*b*) Bound with thin iron wire in position.

they have the same characteristics. Contrary to what perhaps would have been expected, copper is the dominant partner. It has a distinct individuality, which is modified, but not extinguished, by the other metals. The curves for the elastic limits, or, more strictly speaking, the yield points, approximate to straight lines, except in the case of copper-zinc, which is probably explained by the large proportion of zinc. The irregularities in the copper-nickel curve are difficult to account for. The breaking-load curves still more closely approximate to straight lines, but show signs of being influenced by the second metal at the higher temperatures. The most distinctive curves are those for elongation and reduction of area. They show the preponderating influence of the copper, and at the same time the modifying effect of the added metal. The more rapid rise above 800° Fah. in

TABLE IV.—*Copper-Nickel, July 23rd, 1909. Rolled 1in. Rod.*

Nickel about 12 per cent.

TENSILE TESTS.

All test-bars annealed ⅓ hour at 650° C.

Temperature of Test.		Yield Point. Tons per Square Inch.	Breaking Load. Tons per Square Inch.	Elongation per Cent. on 2 Inches.	Reduction of Area per Cent.
Deg. Fah.	Deg. C.				
55	13·0	9·3	18·1	55·5	63·0
200	93·3	9·25	16·2	55·5	79·0
300	150·0	9·0	15·1	54·5	79·5
350	176·7	7·6	14·1	57·0	77·0
400	204·0	7·4	14·1	55·0	76·0
450	232·0	8·0	13·4	52·0	71·5
500	260·0	7·5	12·8	49·0	65·0
550	287·8	7·8	12·3	43·5	60·0
600	316·0	7·7	11·8	39·0	53·0
700	371·0	8·2	11·55	35·5	54·5
800	427·0	8·7	11·9	37·5	54·0
850	455·0	7·13	9·9	27·5	41·0

TABLE V.—*Copper-Aluminium, December 7th, 1900. Rolled 1in. Rod.*

Analysis.

	Per Cent.
Aluminium	7·15
Iron	0·115
Silicon	0·027

TENSILE TESTS.

In tests marked * test-bars were specially annealed in laboratory 2 hours at 600° C.

Temperature of Test.		Yield Point. Tons per Square Inch.	Breaking Load. Tons per Square Inch.	Elongation per Cent. on 2 Inches.	Reduction of Area per Cent.
Deg. Fah.	Deg. C.				
60	15·5	4·26	23·86	91·0	72·9
400	204·0	*4·93	20·94	81·0	58·2
500	260·0	*4·31	17·95	49·0	43·7
600	316·0	4·93	14·56	25·0	30·4
800	427·0	4·93	10·02	12·0	16·0
900	482·0	2·84	6·25	13·0	25·4

TABLE VI.—*Copper-Zinc, January 16th, 1900. Extruded Rod.*

Zinc about 40 per cent.

TENSILE TESTS.

In tests marked * test-bars were annealed 2 hours at 600° C. All other bars annealed, but temperature not recorded.

Temperature of Test.		Yield Point. Tons per Square Inch.	Breaking Load. Tons per Square Inch.	Elongation per Cent. on 2 Inches.	Reduction of Area per Cent.
Deg. Fah.	Deg. C.				
60	15·5	*5·96	26·13	50·5	66·3
400	204·0	*7·67	20·11	64·0	70·8
400	204·0	7·95	19·56	63·5	72·9
500	260·0	7·38	17·56	67·5	66·3
600	316·0	5·68	12·47	35·5	48·1
700	371·0	1·98	6·85	36·0	45·2
800	427·0	1·13	3·48	27·0	39·1

TABLE VII.—*Mild Steel, March 23rd, 1900. Rolled 1in. Rod.*

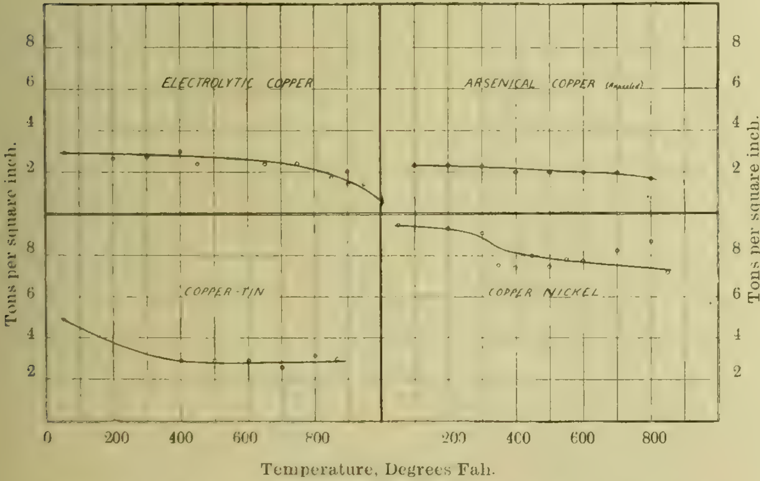
Analysis.

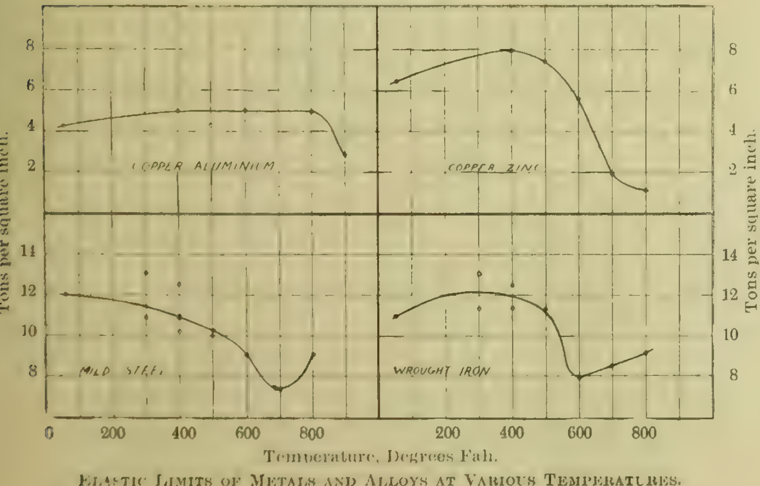
	Per Cent.
Silicon	0·053
Sulphur	0·041
Manganese	0·401
Nickel	0·045
Phosphorus	0·138
Carbon	not determined.

TENSILE TESTS.

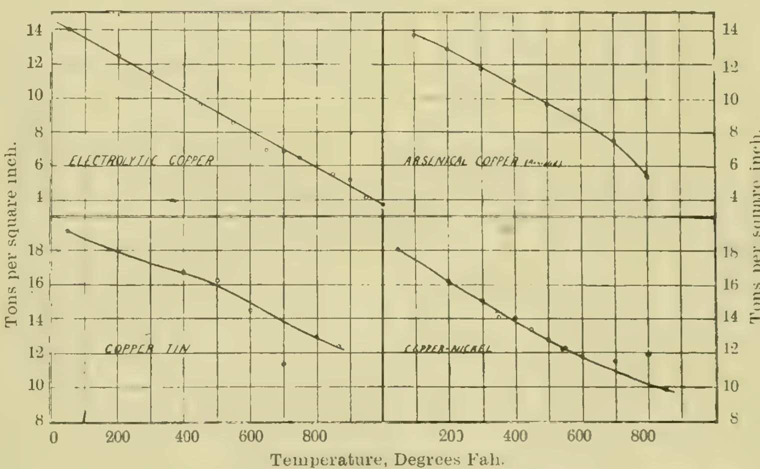
In tests marked * test-bars were specially annealed in laboratory at 600° C.

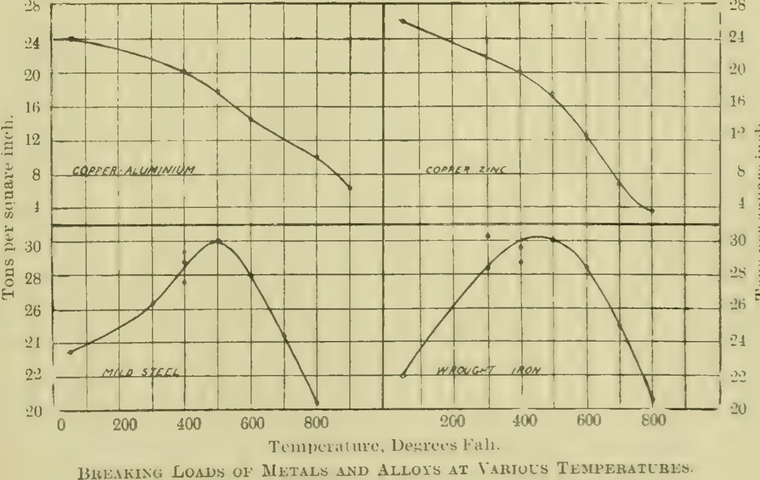
Temperature of Test.		Yield Point. Tons per Square Inch.	Breaking Load. Tons per Square Inch.	Elongation per Cent. on 2 Inches.	Reduction of Area per Cent.
Deg. Fah.	Deg. C.				
*57	14	11·98	23·55	42·0	68·6
300	150	10·79	26·27	25·0	61·5
300	150	13·06	26·77	22·0	61·5
400	204	10·22	27·54	25·5	53·7
400	204	12·50	28·77	25·5	56·4
400	204	10·85	29·4	24·0	49·0
*400	204	12·5	28·27	24·0	59·0
500	260	10·22	30·0	23·5	53·7
500	260	10·0	25·6	34·0	60·5
600	316	9·09	27·9	29·0	56·4
700	371	7·38	24·31	35·0	64·0
800	427	9·09	20·34	30·0	68·6





ELASTIC LIMITS OF METALS AND ALLOYS AT VARIOUS TEMPERATURES.





BREAKING LOADS OF METALS AND ALLOYS AT VARIOUS TEMPERATURES.

TABLE VIII.—*Wrought Iron, March 28th,* 1900. *Rolled 1in. Rod.*

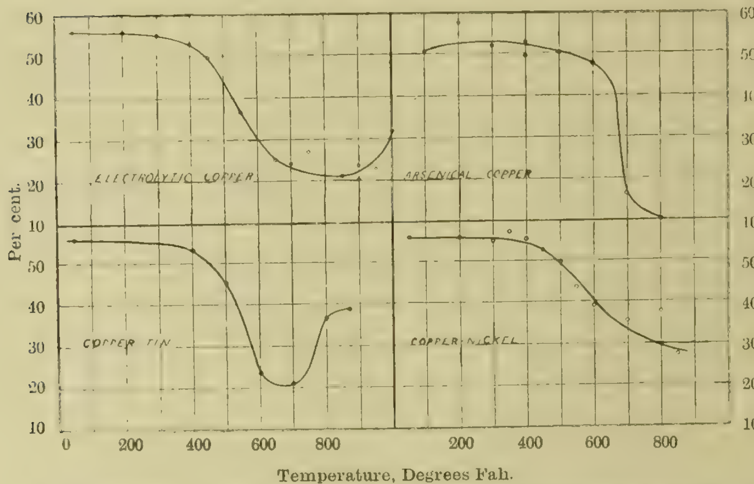
Analysis.

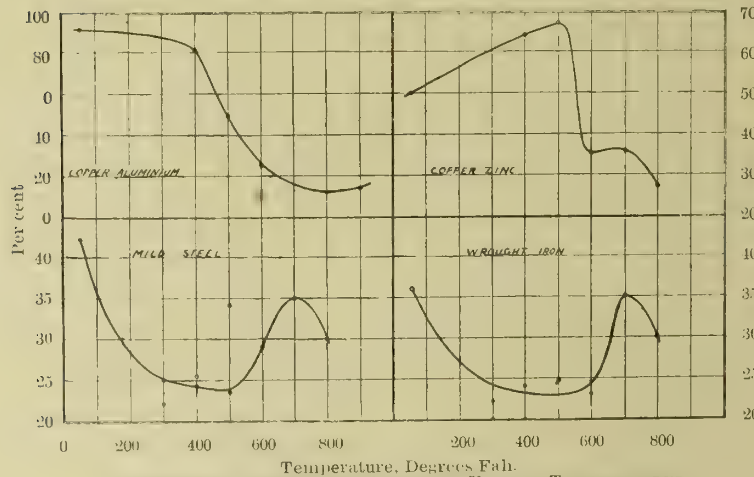
	Per Cent.
Silicon	0·130
Sulphur	nil
Manganese	nil
Nickel	nil
Phosphorus	0·143
Carbon	not determined.

TENSILE TESTS.

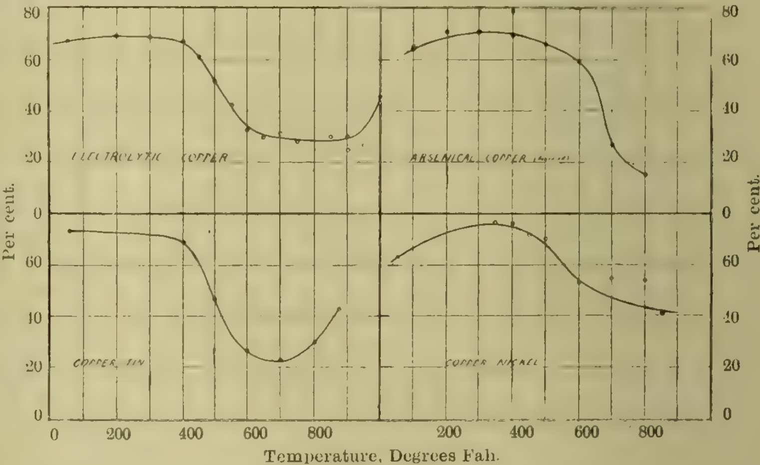
In test marked * test-bar was specially annealed in laboratory 2 hours at 600° C.

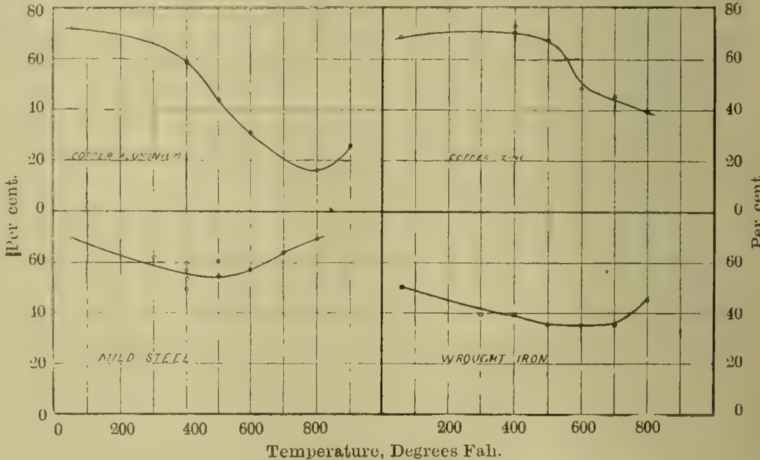
Temperature of Test. Deg. Fah.	Deg. C.	Yield Point. Tons per Square Inch.	Breaking Load. Tons per Square Inch.	Elongation per Cent. on 2 Inches.	Reduction of Area per Cent.
57	14	10·8	22·0	36·5	50·0
300	150	11·36	30·27	22·0	39·1
300	150	13·06	28·36	20·0	39·1
400	204	12·50	29·54	24·0	39·1
400*	204	11·36	28·77	20·0	39·1
500	260	11·36	30·00	24·5	36·0
600	316	7·95	28·45	23·0	36·0
700	371	8·52	25·00	26·0	36·0
800	427	9·09	20·59	20·0	45·2





ELONGATION OF METALS AND ALLOYS AT VARIOUS TEMPERATURES.





REDUCTION OF AREA OF METALS AT VARIOUS TEMPERATURES.

the copper-tin curve, the steady rise to 500° Fah. in the copper-zinc curve, and the close resemblance between the electrolytic copper and the copper with 7 per cent. of aluminium are all interesting. The reduction of area curves have a close resemblance to the elongation curves, except that the reduction of area up to 500° Fah. in the copper-zinc curve does not show the considerable rise which occurs in the elongation.

Although this Institute does not concern itself directly with iron and steel, their curves are inserted here for precisely the same reason that they were made, viz., for comparison, in order that it may be seen in what ways copper resembles or differs from these important structural metals. It will be seen at once that there are very great differences. In the yield-point curves the only resemblance to iron and steel is found in the case of copper-zinc. In the breaking-load curves iron and steel are markedly different from the others. In the elongation curves, instead of the approximately horizontal portion found in the case of copper and its alloys, except copper-zinc, which shows a steep rise, iron and steel at once exhibit a rapid drop in elongation. In the reduction of area curves also there are considerable differences. Although there are not many points on the iron and steel curves, the close resemblance between these curves leaves no doubt as to their substantial accuracy.

It is fairly certain that engineers have hitherto expected a reduction of elongation with an increase in the breaking load in a given metal or alloy. They have been justified in this by the behaviour of iron and steel at atmospheric temperatures, and they are still justified. At such temperatures as these, metals would be used in the Arts. That they are not justified in applying this rule to copper and its alloys is manifest from an examination of the curves in this paper. It will be seen that, whilst the breaking loads are essentially straight-line curves, the elongation curves are contorted in perfectly definite ways, which, however, have no relation to the breaking loads. These are exceedingly interesting points and worthy of further study. It is somewhat remarkable that they have escaped observation and investigation so long. That they have done so is probably due to the fact that in such experiments as have been made, insufficiently pure metal has been used, the points observed have been taken too far apart, the test-pieces have not been suitably annealed to make the tests comparable, and not improbably the carrying out of the tests has left something to be desired.

It is difficult to conceive that the definite and strongly-marked changes in direction in the elongation curves are not due to molecular disturbances. It is still more difficult to imagine these marked molecular disturbances leaving the breaking loads unaffected to a corresponding extent. Yet that is what takes place in the case of copper and its alloys, and with iron and steel above a certain temperature.

The range of temperatures given in this paper is restricted to such as might occur during the use of these metals and alloys in the Arts. What occurs during the manufacture

and working of these metals and alloys is a different matter altogether, and was not the object of the investigations. Numerous tests of other kinds than tensile were also made, which cannot be described on this occasion. It is intended to get out the curves for nickel, for which purpose rods were obtained some years ago.

The tests contained in this paper were carried out by different assistants, most recently by Mr. Licence and Mr. Baker. The author takes this opportunity of expressing to all of them his gratitude for the zeal and efficiency which has invariably characterised their work.

SOME FEATURES OF STEEL RAIL TESTING.*

BY JAMES E. HOWARD.

THE mechanical test of steel rails may be considered in conjunction with service stresses, track conditions, and metallurgical structure. The principal stresses to which steel rails are subjected under service conditions are: (*a*) transverse bending as a beam; (*b*) crosswise bending of the flanges of the base; (*c*) direct compression and cold rolling of the head; (*d*) shearing stresses; and (*e*) abrasion from the treads and flanges of the wheels.

These constitute the service stresses, to provide for which adequate provision should be made in the design of the rail and the selection of the material. The passage of a train over the track is attended with the development of these stresses. However, track conditions are such that, while the kind of stresses admits of recognition, their magnitude does not. That is, the yielding character of the road bed introduces modifying conditions which make it impracticable to accurately judge of the fibre stresses involved when a given wheel load is carried by a rail of definite moment of resistance and known physical properties. It has been experimentally found that the stress per square inch per ton of wheel load varies materially with the different wheels of a locomotive, the observations being made under static conditions. Eccentricity of loading the head commonly occurs, the greater stress being received at the gauge side.

Generally, or perhaps invariably, the wheel loads overstrain the running surface of the head of the rail, change the density of the steel locally, and introduce internal strains of a permanent character. When this zone is worn away by abrasion, the zone of metal next below in its turn is affected by internal strains. Apparently, the penetration of these internal strains may extend far into the metal of the head. Alternate stresses of tension and compression are received by the rail acting as a beam, by reason of differences in position of the wheels, and the surface cold rolling of the head also is subjected to reversal of stresses longitudinally. Cold rolling and abrasive influences cause a downward flow of the metal at the gauge side of the head and lateral flow on the top.

To meet these conditions the metal of the rail should be structurally sound. But to attain structural soundness and uniformity in the finished rail, certain conditions must prevail in the ingot and during the reductions in the rail mill. Chief among these is the elimination of slag inclusions in the ingot, which, starting in a globular form, become acicular in the rail and oriented parallel to its axis.

Several conditions as they now prevail require rails of a considerable degree of hardness chemically, to ensure durability against abrasive wear and cold flow under the wheel pressures. The rail would be a superior one in which these effects are minimised. It is obvious that the extent to which flow under the cold rolling of the wheels can take place without inducing rupture will be less in the case of hard steels than for soft and medium steels.

A consideration of the service stresses, track conditions, and structural soundness of the rail is suggestive of the mechanical tests which are applicable and adequate to secure suitable metal in a rail. A knowledge of the actual fibre stresses which are developed in the rail when in the track is fundamental in judging of the physical properties essential in the rail. The chemical composition of the metal will be established in accordance therewith.

The reductions in the rail mill from the ingot to the finished shape clearly ensure well-worked steel. In the presence of such evidence, a test having for its object the demonstration of well-worked steel would appear to be only supplementary or confirmatory in its character. Prescribing a definite and exact amount of extension in the rail in the direction of its axis either in the head or the base, is a matter which presents logical difficulties, since steels in general under the effect of repeated alternate stresses rupture without appreciable display of extension.

The longitudinal laminations common to rails of current manufacture, in the light of numerous failures in the track, point to the need of mechanical tests to ensure against the acceptance of rails containing such defects. Such tests should also have a salutary influence toward effecting an improvement in the finished rails. The test now referred to would consist of bending the flanges of the base in a direction at right angles to that at which the base is strained in a drop test (which is longitudinally). Recent tests of this kind show widely divergent results in the resistance of base flanges due to the laminated condition of the metal, and a degree of brittleness comparable to that displayed by rails which develop flange breaks in service.

When it shall become known what fibre stresses are caused by the wheel pressures of current rolling stock, a transverse test in which the resistance of the rail is measured, as in an ordinary beam test, will afford desirable information as to the margin in strength which may exist between the working fibre stresses and the transverse elastic limit of the rail.

Special tests of an investigative, metallurgical nature for common guidance in mill practice in providing structurally acceptable ingots appear to be needed, to permit of simplifying those tests which are made for the acceptance of the finished rails. The acceptance tests would then have direct reference to securing a rail of suitable strength to meet definite service stresses, and of such resistance against abrasion and cold rolling effects of wheel pressures as will make it a safe rail for permissible loads.

* Paper presented at the International Congress for Testing Materials.

Safety of Steel Railway Cars.—Sir Edgar Speyer, presiding at the recent half-yearly meeting of the Underground Electric Railways Company of London, said anything that human ingenuity could contrive to make the railways absolutely safe would be adopted. While they deplored the accident which unfortunately occurred on the Piccadilly Railway on September 4th, they could point with pride to the magnificent record made by the London railways. Steel cars were exclusively used on the "tubes," and the wisdom of the management in adopting this material had been amply vindicated. As the cars withstood the shock remarkably well, and as they were immune from fire, they had proved a great element of safety. Since the opening of the London Electric and electrification of the District Railways 929,315,363 passengers had been carried, 41,109,664 train miles had been run, and in the movement of the trains the signals had been operated over 2,400,000,000 times, all of which had been accomplished without a single fatality due to a failure either in the rolling stock or signal system.

Gob Fires in Mines.—In the course of a lecture on "Gob Fires and Spontaneous Combustion in Mines," recently delivered by Prof. Bowell, of the University of Leeds, he observed that some gob fires were of extremely long duration. In 1861, in a mine in Saxony, there existed a gob fire which Agricola in 1556 stated had even then been burning since time immemorial. In any case, the existence of a gob fire in a mine must cause great anxiety to the management. Spontaneous combustion was attributed to three main causes: oxidation of the coal, oxidation of iron pyrites, and heat due to friction from pressure of the roof. The chemical action of oxidation produced heat, and the heat thus generated promoted further oxidation. It further appeared that sunlight lessened, or retarded, this action, consequently coal underground was favourably situated for the absorption of oxygen. In Yorkshire, though gob fires occurred in several seams, they were comparatively rare in the really gassy seams, except in the Barnsley bed in the Doncaster district. Undoubtedly, the best preventive method was to fill up all the empty spaces with incombustible material such as sand. In some continental mines this practice was followed, the sand being washed down the pits into the waste spaces by water through a system of pipes.

A NEW METHOD OF CASTING SMALL INGOTS.

THE "Revue de Metallurgie" has an interesting article by M. J. Corbiau describing a new method of casting small ingots devised by M. Defays-Lanser, an engineer of Brussels. It is particularly applicable to small rolling mills and plants which are now dependent on outside sources of supply for their billets, as it offers a promising method for casting large numbers of small ingots successfully, in good condition to be rolled directly in small mills. There has always been great difficulty in casting small ingots. For instance, a 165lbs. to 175lbs. ingot and a 15-ton open-hearth furnace would mean about 192 ingots. These may be arranged in 48 groups of four, or 32 groups of six, using bottom pouring. After pouring, the groups are united by the steel from the runner spout and the breaking of this steel requires long and laborious supplementary hand labour. Further, when the moulds have been used for some time the steel sticks, and the stripping is made long and difficult. For these reasons the pouring floor is not cleaned up for a long time, and if the next heat should come a little ahead of time the moulds are not set up ready for pouring, which of course retards the operation.

In order to guard against these inconveniences M. Defays-Lanser has worked out a method that, in addition to other advantages to be examined later, allows all the runners of steel uniting the ingots to be sheared at one operation, and so makes possible rapid and easy stripping. In this process the moulds are formed by plates with properly-shaped vertical grooves. The plates are placed touching each other, and the grooves form cells in which the steel is poured. The pressure necessary to hold the plates tightly against each other may be supplied by hydraulic cylinders, steam, or compressed air.

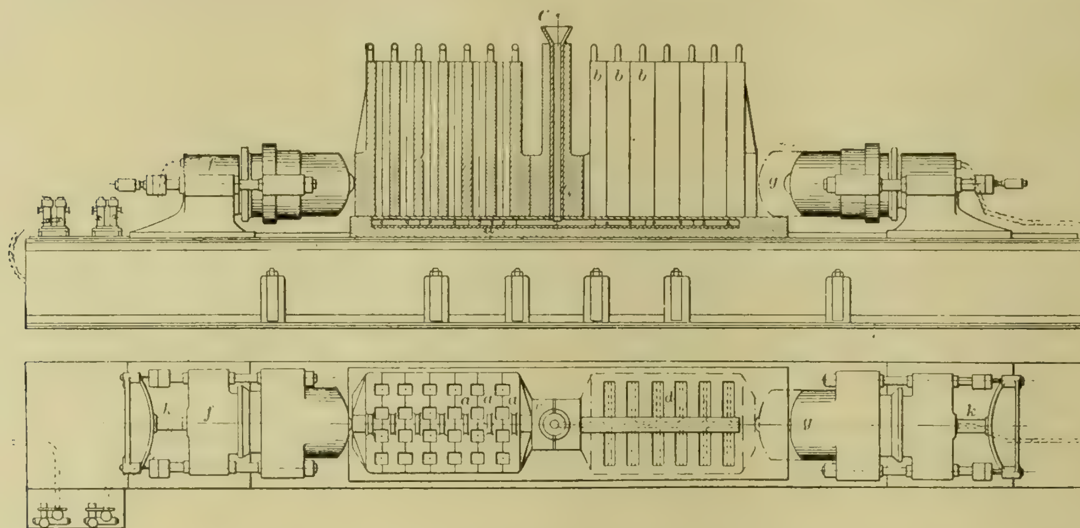


FIG. 1. DEFAYS-LANSER METHOD OF CASTING SMALL STEEL INGOTS.

One method of applying this invention is illustrated. At *a, a, a* and *b, b, b* are two series of plates which are pressed together to form the moulds; *c* is the central pouring funnel, *d* the bottom bricks, and *f* and *g* two identical hydraulic cylinders working in opposition, which serve to keep the plates tight against each other. The two small hydraulic cylinders *k, k* serve to bring the pistons of the cylinders *f* and *g* back to position. The operation is simple. Before casting, the piston *g* alone is exerting pressure, and is in the position shown by dotted lines. When the casting is over and a short time has elapsed to enable the steel to set in the bottom runner bricks, the piston *g* is brought back by means of the little cylinder *k*, and pressure is admitted to *f*. Under this pressure everything is moved bodily; the runners of steel from the pouring funnel to the separate ingots are all cut close to the base of the ingots, so that the latter are now entirely separate from each other. Afterward the pressure is released and the ingots are easily stripped from the plate ingot moulds.

This process has several important advantages. First of all is the rapidity with which the steel can be stripped and the moulds properly set up again. In this way the operation of the furnace is not slowed down, and the ingots can be delivered hot to the mills, which reduces the cost of reheating. Further, steel ingot mould plates can be used, which stand up much better than cast iron, and the plates can be easily examined and kept in good repair.

The method is then compared in detail with that of bottom pouring ordinary small ingots weighing about 175lbs., 4·72in. × 4·72in. × 31·5in., in groups of four, the steel being taken from a 15 to 16-ton open-hearth furnace. It will need 48 groups of 4 ingots per heat, corresponding to about 15 tons of steel. In a year of 250 working days this will amount to about 15,000 tons. First, the saving in brick is considerable, for in the new process the ingots are poured very near together. Under Belgian conditions this is calculated to amount to £250 per year. The consumption of moulds will be less with the new system, although it must be remembered that they will cost considerably more at the start, because of the greater care necessary in making them, so that the joints may fit closely. Paying due attention to this, and figuring that the scrap value of both kinds of moulds is the same, the annual saving in favour of the new moulds is given as £108.

The bottom pour waste will be considerably less with the new system. In this particular case the gain will be 690lbs. per heat, or 690 tons of ingots per year. Under Belgian conditions this represents an annual saving of £500 over the scrap value of the bottom pour scrap. The labour necessary will be reduced, two men per shift being saved, which means £200 per year. The next point is the use of the ingots in the rolling mill. Ordinary ingots are usually tapered to assist in stripping, but with the new system they can be of the same section throughout, just like billets. This is very important, as the head of the ingot should be worked more than the rest, but at present it is the part worked the least during the first passes when the temperature is the best to allow welding. With the new system it would be easy to make the head larger than the base of the ingot, or to cast round ingots suitable for making seamless tubes, or flat ingots for slabs and plates.

A small Belgian rolling mill using this system has found that 109 tons of ingots are necessary to give 100 tons of finished steel. The results of previous practice were 112 tons of ingots cast in the ordinary way, or 106 tons of billets. Taking these figures as a basis the use of 15,000 tons of ingots cast by the new method would give 370 tons more finished material than old style ingots per year. In the latter case this 370 tons would be scrap. The gain would be £1,036. The total of these sums shows 2s. 9½d. per ton in favour of the new system.

Certain plants use moulds with four or six compartments in order to facilitate setting up the moulds, stripping, and keeping the casting floor clean. Such moulds are certainly better than ordinary ones, but the new system is still more advantageous. Calculations are given in the original paper to prove this. No account has been taken of the cost of the power necessary to operate the new method, but this must be small.

The main objection to be raised is the difficulty of maintaining a close fit between the plates, as cast iron will burn after being in contact with liquid steel a certain time. The use of cast steel plates should be carefully considered, as these will stand up much better than cast iron. In this connection it may be mentioned that recent tests have shown that ordinary moulds of cast steel are very satisfactory.

In conclusion, the Defays-Lanser process offers important advantages in regard to ease and rapidity of operation. It also considerably lowers the conversion cost from the furnace to the finished product. In comparison with the ordinary methods of bottom pouring small ingots, it gives a saving that quickly pays off the cost of the original installation. It does not take up much room and so allows the cost of buildings, &c., to be reduced.—"The Iron Age."

INDUSTRIAL AND TRADE NOTES.

Cumberland Ironworkers' Wages. — The quarterly ascertainment under the sliding scale in force in Cumberland shows that the average selling price of hematite iron warrants was 76s. 9d. per ton, compared with 70s. in the previous quarter. The Cumberland blastfurnacemen's wages, therefore, advanced by 8½ per cent., and are 19 per cent. higher than in the corresponding quarter of last year. They are now 46 per cent. above the standard.

English Tube Prices Advanced.— The English Wrought Iron Tube Makers' Association has declared a reduction in gross discounts of 1¼ per cent. upon black gas and galvanised tubes, and of 2½ per cent. upon steam and water tubes. This is the fourth advance since January. The gross discount on gas tubes now becomes 66¼ per cent., water tubes 65 per cent., and steam tubes 62½ per cent. The alteration means an advance of 12½ per cent. on steam and water tubes.

Scottish Moulders' Wages to be Advanced.—At a conference recently held in Glasgow of representatives of the Scottish Employers' Federation of Iron and Steel Founders and representatives of the moulders employed by them, it has been agreed that wages shall be advanced one farthing an hour to pieceworkers employed by the hour, and 1s. per week to day men employed in the marine and jobbing works connected with the Federation. The advances are to come into force on the 5th December next.

New Ironworks at Irlam.— The new works under construction for the Partington Steel and Iron Company, Ltd., at Irlam, adjoining the Manchester Ship Canal, are progressing, and it is anticipated that two blastfurnaces will be ready to start operations early next year. Most of the steel structural work in connection with the furnaces is completed, and also the greater part of the foundations for the steel smelting and rolling departments, while the contracts for engines and machinery are well in hand. Most of the by-products plant is installed.

New Factory for Marine Oil Engines.— It is announced that Harland & Wolff have sold to the recently-formed Burmeister and Wain (Diesel System) Oil Engine Company, Ltd., the engineering and boilermaking shops at Govan, which it acquired in February of this year from the London and Glasgow Shipbuilding Company. The works in future will be devoted entirely to the manufacture of oil-engines for marine purposes. Harland & Wolff will retain their Glasgow shipyard, and will probably obtain from Belfast what steam engines they require for the ships built there.

International Exhibitions. — The Secretary of State for Foreign Affairs has appointed the following gentlemen to represent the Government at the forthcoming conference at Berlin for the regulation of international exhibitions: Sir Alfred E. Bateman, K.C.M.G., Mr. U. F. Wintour, director of the exhibitions branch, Board of Trade, and Mr. Walter F. Reid, F.I.C.S. Mr. E. Wyldbore-Smith, exhibitions branch of the Board of Trade, Mr. H. G. Chilton, second secretary at the British Embassy, Berlin, and Mr. R. F. H. Duke, exhibitions branch of the Board of Trade, will act as secretaries to the British delegates.

Novel Departure in Rolling-Stock Contracts.—To meet repeated complaints from the Indian trading community, voiced principally by the Bengal Chamber of Commerce, as to the serious shortage of freight rolling stock on the Indian State Railways the Indian Office have, in order to make up for the long restricted indents during recent years, now decided upon an interesting departure, inasmuch that they have decided to purchase rolling stock upon the deferred payment system. In this connection an order has been placed with the Metropolitan Amalgamated Railway Carriage and Wagon Company, Birmingham, for 3,000 freight wagons of various types.

The Nationalisation of Mines.—The Bill which has been drafted by a special committee of the Miners' Federation for the nationalisation of the coal mines and minerals of the United Kingdom and to provide for the national distribution of coal was presented to the delegates of the Miners' Federation conference on the 3rd inst. for their consideration and approval. The Bill, which consists of 19 clauses, was discussed at length, and ultimately the proposals contained in it were unanimously approved. It was agreed that they should be forwarded to the annual Congress of the Labour Party in January next, to get the Bill, as drafted, officially adopted by the party.

Imports of Motor Vehicles into Russia.—The import trade of Russia in automobiles, including motor cycles, has, during the last 10 years, made rapid strides. In 1902 the number of vehicles imported was 37, valued at £8,400. In 1906 the number had increased to 595 valued at £110,140, while in 1911 the total reached 3,851 vehicles valued at £1,082,540. H.M. Embassy at St. Petersburg states that the motor industry in Russia is still in its infancy, and the increasing demand for automobiles indicates a great future for this branch of trade. In 1909 no motor cars were registered in St. Petersburg, but there were 1,056 in 1910, and 1,179 in 1911; 264 motor cars were registered in Moscow in 1909, 518 in 1910, and 826 in 1911.

Labour Co-partnery.—The annual report of the Labour Co-partnership Association just issued shows that there are now 110 societies based on the co-partnership principle in Great Britain, only five of which are in Scotland. The Scottish societies are, however, much larger than the others. The total capital involved in Great Britain in these societies is £1,991,551, of which £1,265,568 is invested in Scottish societies. The trade done last year amounted to £4,681,428, the Scottish societies being responsible for £3,059,752. The total profits of the individual societies amounted to £228,180, and the losses to £5,060, the greater part of which is attributable to agricultural societies. The amount paid in dividend on wages was £29,847.

State Railways.—Advocates of railway nationalisation sometimes affirm that the United Kingdom is one of the few countries in the world which have not resorted to State ownership of railways. While it is true that most other States have tried their hands at railway making and managing, it is interesting to note that at the present time the nationalised railways are almost insignificant in the matter of mileage of track. According to Mr. E. A. Pratt, a well known authority on the subject, the total length of the world's railways is 639,621 miles, and of these 453,553 miles are owned by private enterprise, and only 186,068 by the various States, the percentages of the whole being respectively 70·9 and 29·1.

Minerals in Southern Nigeria.—A report by Prof. Wyndham Dunstan, director of the Imperial Institute, on the results of the mineral survey of Southern Nigeria in 1910, has recently been published. Prof. Dunstan is of the opinion that the results obtained during 1910 have largely extended existing knowledge of the economic mineral resources of Southern Nigeria. Previous reports had referred to the important lignite (brown coal) and sub-bituminous coal deposits occurring in the country, and further valuable contributions are now made to present knowledge of the extent and quality of these fuel resources, which are likely, it is thought, to be of great importance in the future industrial development, not only of Southern Nigeria, but also of the whole of West Africa. Details are given in the report of the results obtained in each separate case from the investigation at the Imperial Institute of all the samples sent there for examination. These samples included concentrates, clays, shales, and coals.

Shipyard Agreement.—The conference held on the 2nd inst at Carlisle between representatives of the Shipbuilding Employers' Federation and the Standing Committee of the Shipyard Trade Unions was only of a preliminary nature, and no decisions were reached on any of the points discussed. The representatives of the men formally submitted their proposals for the amendment of the national agreement. These proposals, as already intimated, include provisions for "speeding up" the machinery for dealing with disputes, so that there may be the least possible delay between the notification of a dispute and its settlement, while the men also wish to have a clause inserted in the agreement providing "that in case of a deadlock, before a strike or lock-out by either side is declared, a further grand conference be held, with a neutral and disinterested chairman, who may, if mutually requested, decide a question at issue." The conference discussed the points raised for some time, and ultimately it was agreed to appoint a sub-committee to consider all the proposals, and report to a future conference.

The Sunderland Engineers' Strike.—The strike of engineers at Sunderland, which has lasted five weeks, has been settled, and the men returned to work on Monday last. The settlement was effected at a conference between representatives of the Amalgamated Society of Engineers and representatives of the Wearside employers. The dispute arose over the question of the employment of unskilled labour on lathe machines, which the engineers claimed was the sole work of skilled men, and was responsible for over 200 men coming out on strike. The terms of settlement are, we understand, purely of a local character, and were arranged without prejudice to the discussion of the employment of unskilled labour on lathe machines which will take place in January after the ballot of the members of the Amalgamated Society of Engineers on the 1897 agreement. The Employers' Federation have consented to Messrs. Lynn paying 37s. 6d. per week—the union wage of the turners—to the man employed on the lathe machine over the working of which the dispute arose. The man was previously paid a less sum than this amount. The terms have been received with approval by the men concerned.

Superheater Locomotives for the L. & Y.—Some new superheater tank engines designed by the chief mechanical engineer, Mr. George Hughes, have been introduced into the passenger service of the Lancashire and Yorkshire Railway. The engines are of the 2—4—2 type, fitted with a Schmidt superheater. The principal measurements, &c., are: Cylinders, 20½in. by 26in.; coupled wheels, 5ft. 8in.; steam pressure of 170lbs. per square inch; heating surface of tubes, 812·8 sq. ft.; weight in working order, 66½ tons.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Combined internal-combustion engines and variable-speed gears. Rowe. 13520.
Pneumatic power hammers. Honeywood & Graham. 14037.
Power hammers. Honeywood & Graham. 14038.
Two-stroke cycle internal-combustion pumps. Siemens Schuckertwerke Ges. 14470.
Firegrates for refuse destructor furnaces. Watson & Watson. 18348.
Ignition apparatus. Danicek, Cernovsky, & Hoffman. 19297.
Construction of pulleys. Barrett. 20186.
Variable-speed gearing. Fellows. 20335.
Roasting of iron ores. Boult. 20404.
Power plants in which liquefied gases of low boiling point are used as motive fluid. Hildebrand. 20471.
Starting clutches for the engines of motor vehicles. Biehler. 20500.
Manufacture of twist drills. Spencer. 20513.
Hauling rope grip for rope railways. Bleichert & Bleichert. 21019.
Rotary pumps and compressors. Parsons & Carnegie. 21111.
Motor vehicles. Grice, and G. W. K., Ltd. 21228.
Mechanism for controlling valves, switches, or the like at predetermined times. Morrison. 21439.
Methods of and apparatus for raising or forcing liquids. Humphrey. 21609.
Control of valves. Pfleiderer. 22688.
Cocks or valves for water mains. Samain. 22694.
Safety lamps. Bryan, and J. Wilson Browne & Son, Ltd. 22723.
Method of producing ferro-silicon. Bingham. 22755.
Collets for feeding bars through the chucks of automatic machines. Herbert & Vernon. 22767.
Apparatus for measuring and delivering quantities of liquids. Cole. 22886.
Aeroplane. Komm. 22942.
Valve mechanism of internal-combustion engines. Brindley. 23664.
Metal beams. Siewert. 24391.
Packing of stuffing-boxes. Bradley. 24404.
Furnace fronts and fire-doors. Wallace. 24736.
Pumps or compressors. Gumprecht & Collingwood. 25574.
Centrifugal fans and pumps. Jacobsen. 25646.
Valve mechanism for 4-stroke cycle internal-combustion engines. Lafitte. 25682.
Refrigerating apparatus. Maschinenfabrik Surth Ges. 26261.
Grinding of toothed wheels. Aichele. 26323.
Winding drums for hoists or cranes. Petersen. 26357.
Governing mechanism for elastic-fluid turbines. Warwick Machinery Company (1908). 27022.
Motors. Walker. 27048.
Aluminium alloys. Naylor & Hutton. 27382.
Valve mechanism for internal-combustion engines. Gaubert. 27452.
Haulage clips. Wood. 27631.
Gas fired continuous kilns. Waterfield. 27864.
Boilers. Yates. 28010.
Turbo-compressors or centrifugal pumps. Warwick Machinery Company (1908), and Collingham. 28980.
Axle boxes for railway wagons. Thomas Burnett & Co., and Burnett. 29111.

1912.

Sand hoppers for moulding machines. Barnes. 279.
Friction planet gear. Fono. 1475.
Safety appliances for pit cages. Reynolds. 2684.
Motors. Soc. des Moteurs Gnome. 2783.
Valve gears for reversing engines such as rolling mill engines. Mobus. 3239.
Acetylene gas generators. Mills. 3295.
Stuffing box packing. De la Cour. 4228.
Utilisation of the heat contained in the exhaust steam from steam engines. Constandse. 4811.
Oxy acetylene blow pipe apparatus. Hoddle, and Thorn & Hoddle Acetylene Company. 5222.
Apparatus for superheating air under pressure. Gobert and Meyer. 5329.
Valve apparatus for percussive rock drills. Rayner. 5519.
Hoisting, hauling and winding apparatus. Lindsay & Couper. 6986.
Two stroke cycle internal combustion engines. Brauer. 7714.
Turbine engines. Cole. 8123.
Apparatus for returning condensation water to steam-generators. Pitschel. 8497.
Film lubricated thrust bearings. Michell. 8885.
Vacuum casting devices. Dicker. 10963.
Moulds for casting columns in situ. Venable. 11066.
Propelling of vessels. Huggins & Tares. 11565.
Internal-combustion motors with slide valve action. Fischer. 12161.
Valve motions. Lichtensteiner. 12306.
Starting of internal-combustion engines. Allison & Skinner. 13058.
Ball bearings. Bruhl. 13132.
Calorimeters. Fery. 13270.
Automatic railway coupling. Eichler & Eichler. 13658.
Variable-speed gearing. Bannister & Johns. 16087.

ELECTRICAL, 1911.

Relays for strengthening weak electric currents. Schiessler. 20320.
Motor-feed mechanism for arc lamps. Booker & Reinecke. 20733.
Working of telegraph and telephone circuits. Heurtley. 20787.
Speed regulation of electrically-driven ring spinning and twisting frames. Siemens Bros. Dynamo Works, Ltd., and Crowley. 20919.
Artificial lines used in duplex telegraphy. Brown. 21000.
Electrical plug and socket connections. Berry. 21054.
Compensating device for telephonic circuits. Brown. 21069.
Telephonic apparatus. Muirhead. 21639.
Vapour electric apparatus. Hewitt. 21828.
Electrical measuring instruments having movable coils. Record. 22656.
Intercommunication telephone systems. British Insulated and Helsby Cables, Ltd., Aitken, Cooper, & Remington. 22983.
Electric-light fittings. Simplex Conduits, Ltd., and Birkett. 22988.
Electrical heating devices. Monnot. 22992.
Electrical switches or contact make-and-break devices. Smith and Cox. 23162.
Electric clutch for controlling railway signals. Johnson and Thorrowgood. 26111.
Electric safety lamps for use in mines. Lowe. 28749.
Electric resistance material. British Thomson-Houston Company. 28869.

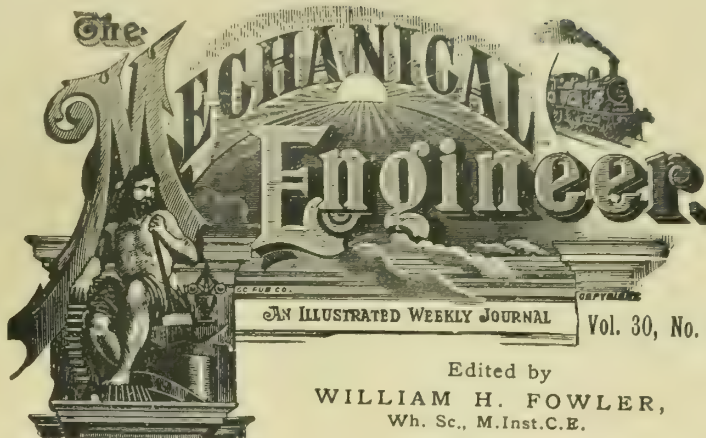
1912.

Electric connecting plugs. British Thomson-Houston Company. 285.
Electricity meters. Landis & Gyr. 1010.
Electric railway systems. Deschamps. 2325.
Intercommunication telephone systems. Corwin. 3097.
Lead storage battery electrodes. Morrison. 7253.
Electric refining crucibles. Marks. 8790.
Electric fuses. Sprong & McCoy. 12701.
Multiple carbon arc lamps. Korting & Mathiesen Akt.-Ges. 14872.
Fuses for use in electrical circuits. Siemens-Schuckertwerke Ges. 19980.

METAL QUOTATIONS.

TUESDAY, OCTOBER 8TH.

Aluminium ingot	82/- per cwt.
" wire, according to sizes, &c. ......from	102/- "
" sheets " " ...... "	120/- "
Antimony ......£35/-/- to	£37/-/- per ton.
Brass, rolled	9⅛d. per lb.
" tubes (brazed)	11¾d.
" " (solid drawn)	10d.
" " wire	9⅛d.
Copper, Standard	£77/-/- per ton.
Iron, Cleveland	66/9 "
" Scotch	73/9 "
Lead, English	£21/15/- "
" Foreign (soft)	£21/12/6 "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£8/-/- per bottle
Silver	29⅝d. per oz.
Spelter	£27/10/- per ton.
Tin, block	£228/5/- "
Tin plates	15/7½ "
Zinc sheets (Silesian)	£31/5/- "
" (Stettin; Vieille Montagne)	£31/10/- "



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Natural Hydraulics.

In this country when hydraulics is mentioned it is artificial hydraulics which is understood, unless distinctly stated to the contrary. And by artificial hydraulics is here meant the flow and behaviour of water or other liquid in artificial vessels, as, for instance, a pipe, a closed chamber, a culvert, or drain, or a piece of machinery, such as a pump or a turbine. The study of this, the artificial, branch of hydraulics is of great interest and importance, but there is another branch of the subject, the study of natural hydraulics, which is probably more interesting and in some fields not less useful than the study of artificial hydraulics. Moreover, natural hydraulics possesses a wider interest than that of bread winning only, and even in this advanced age has about it an air of mystery, uncertainty, and of advance into an unknown which has a charm for engineers as for other men. For these reasons we venture to direct our readers' attention to the study of the behaviour of water under natural, or semi-natural, conditions. The sea, the streams, and even the gutters of our streets provide material for this study. The sea is specially fascinating because of its importance and for less tangible reasons. How many people have tried to form an estimate—to call it a calculation would be too dignified—of the frictional drag of the wind on the sea? Yet there is considerable material to work upon. Thus in a strong sea wind one finds that the tide rises a foot higher in the harbour than it should, and from the weather reports it is possible to determine roughly the strength, direction, and fetch (or distance of travel) of the wind, which lifted the water an extra twelve inches at the coast, gradually tapering off to nothing on the outer edge of the storm zone.

A few such observations, coupled with careful note of the heights of the waves, and with due regard to the lie of neighbouring lands, furnishes matter for interesting specula-

tion which when advanced sufficiently far would be of considerable practical service, particularly to navigators. The tides and the waves have been studied to some extent, but there is much about waves, for instance, that is unknown, and almost all of it is largely empirical, although at the same time resting on a sufficient basis of scientific principles to make the study interesting. In a way it is curious that we know so little about sea waves. Navigators tell of waves 100ft. high and 1,200ft. or 1,500ft. from crest to crest, but those who have investigated such matters generally place the limit of height of a deep-sea wave at 50ft., or at most 70ft., and the length 600ft. to 1,000ft. Everyone who has been at sea in a good storm must, unless too seasick, have been impressed with the apparent height of those waves, which are separated only by a trough, as compared with the waves even a few hundred yards away. Literature, indeed, is full of awe-striking descriptions of waves which rise up "mountains high," as if to topple on board the ship. The explanation is simple enough. The sides of a wave slope, and a ship tends to float more or less flat on the water and not vertical. Hence, the deck is sloping down at an angle of, say, 15°—which is quite a considerable inclination. The observer on the ship tends to adjust his glance to the direction of the deck slope, which is his foundation, and hence the crest of the wave opposite appears to be higher than it really is by the extra 15° we have spoken of. Thus it comes about that even observations made with scientific instruments frequently give impossible results because the observer overlooks or neglects to allow for the sloping deck. The force exerted by a wave is a matter of great practical importance. In the early days of harbour engineering it was believed that wave action was not felt below a depth of about 12ft. below low water, but experience has demonstrated that wave action is felt at much greater depths—in storms, of course. A classic instance of this is afforded by the breakwater at Peterhead, which was disturbed to a depth of 36ft. or 37ft. during a storm in 1898. It should be noted, too, that Peterhead is situated on the east coast of Scotland, and does not receive quite such great waves as are to be met on the west coasts of Europe, including the British Isles. The disturbing power of a wave below the surface is, however, not altogether a matter of the size of the wave as of its rapidity of movement, for these storm forces are obviously kinetic. Moreover, it is interesting to note that waves frequently dislodge, say, stones from a breakwater *outwardly*. The explanation seems to be that the water finds or creates a crack leading from the sea face round the sides and back of the block of stone or concrete. A wave strikes the sea face (which may be submerged) and puts the water filling the crack under a considerable hydraulic pressure. When the wave movement relieves the pressure the relief inside the crack lags behind that at the sea face, and there is an unbalanced outward pressure which moves the stone outwards a little. It is for this reason that we frequently read, as in the case of Peterhead, above referred to, that the stones were moved by the recoiling waves. It is really the hydraulic pressure set up behind the stones in the majority of cases.

Waves do not, however, exhaust the interest of the hydraulic engineer in the sea. Few things are of more importance in practice, and, it must be added, few more difficult to thoroughly understand, than the modifying influences of harbour works, such as breakwaters and piers. In a general way it is known that a harbour tends to silt up because of the slackness of the water, and it is known that a breakwater protects in the path of the wind over it, but these elementary statements barely touch the fringe of the subject, which is as full of enticing problems in scour, silting-up, drift, breakwaters, the field of influence of a breakwater, the directions of probable storms, and in the navigation of ships in distress and otherwise, as anyone could well wish.

Turning now to rivers, we find these just as full of interesting problems, the more so because the conditions are so changeable. Waves in rivers are generally important only when they are permanent waves. Such are substantially determined by the configuration of the river sides and bed. Although, of course, allowance must be made for losses due to friction, Bernoulli's theorem that the sum of the kinetic and potential energy is constant holds true for a river as for the laboratory and the pipe-line. When we remember that the velocity is inversely proportional to the water cross-section of the river (although this is not always indicated with any truth by the surface width) it is easy to see that the surface of a river is not a uniform slope, but is a succession of long, flat waves. Moreover, for purposes of navigation in deep rivers these waves can be flattened and the depths of water over the shallows increased by suitable modification of the velocity of flow, as by submerged weirs, groins, or training walls. Similar principles apply to the smaller but more easily distinguishable permanent waves due to local obstructions in the bed of the river. It is thus possible to read the bed from the surface, even when the former cannot be seen. All these phenomena, for those of an experimental turn of mind, can be studied by means of models, which in a few hours will reproduce the effects of years of tides or the eroding and silting action of long-continued river flow in producing a permanent régime.

Finally, a word may perhaps be said as to the suction of ships, which was raised to a question of public importance by the collision between the "Hawke" and the "Olympic" off Southampton. The suction of ships is most marked in confined waters, such as a river or canal. For instance, if a ship with a cross-section of 1,000 sq. ft. passes down a canal having a section of 2,000 sq. ft., it is clear that the net section between the ship and the sides is reduced to 1,000 sq. ft. (actually to less than this), and since the ship does not push the water before it there must be a flow created past its side and under its bottom to fill in what would otherwise be the vacuum behind it. Hence the water acquires kinetic energy and therefore loses static energy. That is, the water level falls in the neighbourhood of the ship, and the ship lies in the trough of a wave which advances with it up the canal or river. But a flow of water will carry with it floating objects, and hence the local flow in the neighbourhood of the ship will tend to carry with it any near-by vessel. At sea, even in wide rivers, this action is not very marked, but in narrow rivers and canals it is of great importance, and ships have been broken loose from their moorings by the suction of passing vessels in the Suez Canal and other confined waters.

The Junior Institution of Engineers.—A meeting of this Institution will be held on Wednesday, the 23rd inst., at 8 p.m., at the Institution of Electrical Engineers, Victoria Embankment, when a paper on "Scientific Shop Management on the Taylor System" will be read by G. C. Allingham, A.M.I.E.E. On Saturday afternoon, the 26th inst., to Monday, the 28th inst., a week-end visit to Sheffield has been arranged, when the works of Messrs. Thos. Firth & Son, Ltd., and Messrs. Cammell, Laird, & Co., Ltd., will be inspected.

HEAVY OIL ENGINES.*

BY CAPT. H. RIALL SANKEY, R.E. (RETIRED), M.INST.C.E.

THE name "oil engine" includes to-day many types and varieties. About 20 years ago there was only one type on the market, represented by such engines as the Priestman and the Hornsby-Ackroyd. These engines used paraffin or ordinary lamp oil, having a specific gravity of about 0·82. This oil requires heat for vaporisation in order to produce an explosive mixture, and engines using it are now included in the category of "heavy oil" engines. Later, in the year 1890, Daimler brought out his petrol engine, in which a volatile oil

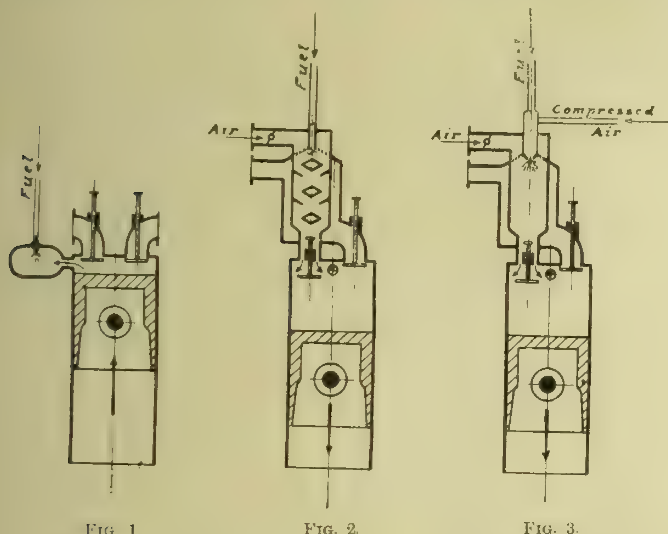


FIG. 1. FIG. 2. FIG. 3.

of 0·680 sp. gr. was used. With such oils vaporisation takes place at ordinary temperatures and air is readily "carburetted," thus forming an explosive mixture. Such engines are called "light oil" engines. Comparatively recently, the Diesel oil engine was placed on the market, and in this type of engine the oil is not vaporised to form an explosive mixture, but is mechanically pulverised, and burns in the engine cylinder, that is, it does not explode in the ordinary sense of the word. The Diesel engine is also a "heavy oil" engine.

There are numerous varieties of each type of engine, sometimes called after the kind of oil they use, such as benzine engines, petrol engines, paraffin engines, and crude oil engines. Incidentally, the latter is a misnomer, because the crude oil is that which comes out of the ground, and contains all the other oils. These engines can therefore be distinguished as follows:—

Light Oil Engines.—An explosive mixture is formed by carburation at atmospheric temperatures. The oils used have a specific gravity as low as 0·68, but usually about 0·72. They are called "petrol engines."

Heavy Oil Engines.—An explosive mixture is formed by vaporisation at comparatively high temperature, or a combustible mixture as formed by mechanical pulverisation, specific gravity of oils, 0·8 to 1·0.

These lectures will be confined to heavy oil engines, and will deal principally with the Diesel engine, as being the most important.

Heavy oil engines can also be classed as: (*a*) Explosive engines; (*b*) combustion engines. Three types of the former are illustrated in Figs. 1, 2, and 3.† Fig. 1 represents the type of the original Priestman engine, in which the oil is vaporised in a hot bulb. Before starting, this bulb has to be heated by means of a lamp, which takes about a quarter of an hour. In Fig. 2 the oil is vaporised by falling on to baffle plates, which are heated by the exhaust, and forms an explosive mixture with the air drawn in on the suction stroke. Such engines are ignited by means of an electric spark, and have to be started by means of petrol, and the heavy oil can be introduced so soon as the baffle plates have reached a sufficient temperature. In Fig. 3 there is a stream of air compressed from 8lbs. to 25lbs. per square inch, which pulverises the oil, after which it is immediately vaporised in the chamber heated by the exhaust gases.

The second class, namely, combustion engines, consists of the Diesel engine and of the so-called semi-Diesel engine. In the former, pure air is compressed in the cylinder to a pressure (450lbs. to 500lbs. per square inch) sufficient to cause ignition, and the oil is pulverised and introduced into the cylinder at the top of stroke by means of air at a still higher pressure (700lbs. to 900lbs. per square inch). In the semi-Diesel engine, pure air is also compressed in the cylinder, but only to about 200lbs. or 250lbs. per square inch, the ignition temperature being reached by means of a hot bulb into which the oil is injected by a pump at the top of the stroke. Judged by the sizes, and the total horse-power at work or under construction, the Diesel engine is to-day the most important type, and will, therefore, be first considered.

The Diesel Engine.—Not many years ago the Diesel engine was known as a promising oil engine to few engineers, but its development has been so rapid—not to say extraordinary—that assuredly everyone, not only engineers, has some acquaintance with it. The reason is obvious, namely, that it can utilise and convert into power types of oil hitherto unusable for power, and it works reliably and with the greatest economy of fuel. This result has, however, only been obtained by long, costly, and patient research and trial.

A short historical account of the developments will, therefore, be of interest, and the following has kindly been supplied by the Maschinenfabrik Augsburg-Nürnberg Company, who were the pioneers in the experimental work.

Dr. Diesel applied for his patents in Germany and other countries in 1892. The Augsburg works of the Maschinenfabrik Augsburg-Nürnberg Company, in conjunction with Messrs. Krupp, of Essen, entered into an agreement with Dr. Diesel to make all tests and experiments for the carrying out of the patents and to install at Augsburg a special laboratory, equipped with all the necessary technical and scientific means for this purpose. The two German patents were acquired at the same time (1893) by the two above-mentioned firms. Dr. Diesel was at the head of the laboratory, but all the costs were borne by the Maschinenfabrik Augsburg-Nürnberg Company and Messrs. Krupp.

It was soon found that the chief idea of Dr. Diesel—viz., to obtain the highest temperature of the cycle before the actual combustion, and to get an isothermic combustion—

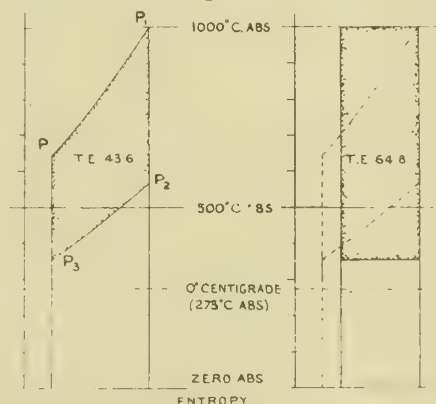


FIG. 4. FIG. 5.

could not be realised, and that water-jacketing of the cylinder, which Dr. Diesel thought he could avoid, was necessary. Notwithstanding these initial disappointments, the owner of the Augsburg works and the Augsburg engineers persevered and succeeded in building, in 1897, the first engine of 20 b.h.p., which was tested by many scientific authorities, and placed the Diesel engine at once, so far as thermal efficiency was concerned, at the head of all prime movers.

This was the first task, the carrying out of which was only rendered possible by sacrifices on the part of the Augsburg works of the Maschinenfabrik Augsburg-Nürnberg Company and Messrs. Krupp. The second task, viz., to build a commercially useful engine, was then undertaken by the Maschinenfabrik Augsburg-Nürnberg Company and their several licensees, as well as by firms in other countries, as, *e.g.*, Mirrlees & Watson, who had bought the patents

* Howard lectures delivered before the Royal Society of Arts, April-May, 1912. Reproduced from the "Journal of the Royal Society of Arts."

† These figures are reproduced by permission of the American Society of Mechanical Engineers, from a paper by H. R. Setz on "Oil Engines."

of their respective countries from Dr. Diesel, after the first scientifically successful engine had been completed at Augsburg.

After the first experiments, however, firms like Sulzer Bros., Carel Frères, Gasmotorenfabrik Deutz, &c., gave the whole thing up, although they had partly received drawings and technical hints from the Augsburg works of the Maschinenfabrik Augsburg-Nürnberg Company. Only the Augsburg works of the Maschinenfabrik Augsburg-Nürnberg Company succeeded, and sold and delivered in the beginning of 1898 an engine of 60 b.h.p. to the match factory "Union," at Kempten, which is still in satisfactory working order. The commercial success attained by the Augsburg works of the Maschinenfabrik Augsburg-Nürnberg Company then induced

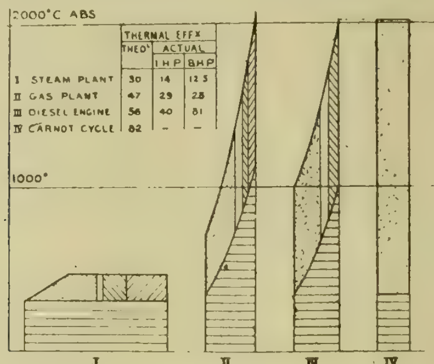


FIG. 6.

other firms, such as Sulzer Bros., Carel Frères, Mirrlees, Bickerton, & Day, and others, to begin again, in 1903-04 or later, the manufacture of Diesel engines.

The history of the English Diesel business is briefly as follows: In March, 1897, Dr. Diesel sold his patents to Mirrlees, Watson, & Yaryan Company, Ltd., and they built an experimental engine. Meanwhile, a special company, "Allgemeine Gesellschaft für Dieselmotoren A.G., Augsburg," had acquired, in September, 1898, all the patent rights of Dr. Diesel. This company bought the patents back from Mirrlees, Watson, & Co., in September, 1899, and entered into a new agreement with this firm in November, 1899. In November, 1900, the "Allgemeine" sold the patent rights for England and the Colonies, and some other countries, to the Diesel Engine Company, Ltd. The Diesel Engine Company then became, and until recently was, exclusively a selling company, and during the first years only sold Diesel engines of the Augsburg works of the Maschinenfabrik Augsburg-Nürnberg Company. The two chief English patents covering the Diesel cycle, and belonging to the Diesel Engine Company, expired in 1906 and 1909, so that the manufacture of Diesel engines can now be attempted by anybody in this country. The Maschinenfabrik Augsburg-Nürnberg Company were, therefore, the pioneers, and have since retained their place at the head of all manufacturers.

A great number of Diesel engines, of the vertical single-acting, four-cycle type, were built by the Maschinenfabrik Augsburg-Nürnberg Company in the following years. When the first really large engines of 600 b.h.p. and 800 b.h.p. were built in 1906-07, it became apparent that they could be built better, simpler, and more accessible on the lines of the then well-proved horizontal double-acting Nuremberg gas engines. An experimental tandem engine of 600 b.h.p. was built at Augsburg, which proved quite satisfactory, and was soon followed by an order for an engine of 1,600 b.h.p. to 2,000 b.h.p. from the Municipal Electricity Works of Halle (Germany). At present 18 such horizontal double-acting engines, ranging from 600 b.h.p. to 2,000 b.h.p., are under construction. Somewhat later, the Maschinenfabrik Augsburg-Nürnberg Company, after exhaustive experiments, also placed on the market horizontal single-acting Diesel engines, of the four-cycle and two-cycle type for medium powers. Since 1903 many firms have undertaken the manufacture of Diesel engines, and today the horse-power at work cannot be far short of one million.

The first reversing marine engine was built by Messrs. Sulzer in 1905 for a boat on the Lake of Geneva, and since then the marine Diesel engine has made rapid strides. Engines of 4,000 h.p. have been built for this purpose, and much larger are in contemplation.

Until recently, the development of the Diesel engine has been slow in this country, due, to a certain extent, to a want of enterprise and to distaste for anything new, especially if it has not originated in this country. The slow development, however, is in large measure due to cheap coal, although this country has an enormous field throughout the Empire, in many parts of which oil, when used in the Diesel engine, is a cheaper fuel than coal.

Thermodynamical Considerations.—All prime movers by means of which useful work can be produced by utilising a "heat fall," can be divided into two main groups, namely, external-combustion engines and internal-combustion engines. The heavy oil engines belong to the latter.

In the case of water wheels and water turbines, a "waterfall" is utilised, and the maximum energy available per pound of water is proportional to the height through which the water falls. Practically, however, only a fraction, varying from, say, 50 to 80 per cent. of this maximum energy, is converted into useful work.

In the case of a heat engine the "heat fall" is measured by the number of thermal units theoretically rendered available for utilisation as work by the change in condition produced in the working fluid by the agency of the cycle operations followed by the particular type of heat engine adopted. In passing through the engine the temperature of the fluid is reduced, but in no actual engine is this fall of temperature, by itself, a measure of the heat fall, because it also depends, and in large measure, on the manner in which the heat is introduced into the working fluid, and on the manner in which it is abstracted therefrom.

The simplest way of exhibiting the above is by means of a heat chart, the ordinates of which represent absolute temperature to an equally divided scale, the base line being at the temperature of absolute zero. Let the point P (Fig. 4) represent the location on the chart of the fluid before any heat is introduced, and let P_1 be its position after heat has been introduced. Further, let the chart be so constructed that the area $P\,P_1\,P_2\,P_3$ represents the number of heat units introduced in some manner or other, and let this amount be H. By virtue of the mechanism of the engine, the heat energy does work which is suitably transmitted to, say, a revolving shaft. Let P_2 represent the condition of the fluid at the beginning of the period of abstraction of heat, and let P_3

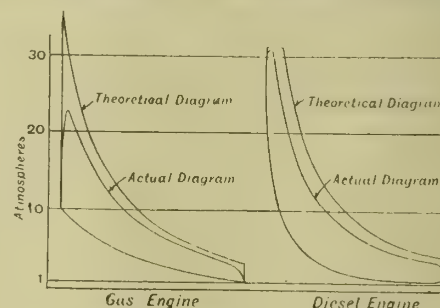


FIG. 7.

represent its condition at the end of this period, then the area $P\,P_3\,P_2\,P_1$ represents the heat abstracted, and clearly the difference between the heat introduced and that abstracted, namely, the heat introduced by the area $P\,P_1\,P_2\,P_3$ is the heat converted into work. Let this amount be represented by W, then the ratio $\frac{W}{H}$ is known as the thermal efficiency of the operation. The endeavour is to make this ratio as large as possible, but, unfortunately, for various reasons, it cannot be made very large.

In Fig. 5 a special case is illustrated, in which both PP_1 and $P_2\,P_3$ are horizontal, that is to say, the heat is introduced at constant temperature, T_1, and is also abstracted at constant temperature, T_3. This figure has been so drawn that the amount of heat introduced, H, is the same as in Fig. 4, and it is clear that the ratio $\frac{W_1}{H}$ is greater in this case than in the former, and it can, in fact, be proved to be the greatest thermal efficiency possible between the temperatures T_1 and T_3.

It can further be shown that each point on this chart defines the condition of the fluid, that is to say, curved lines can be drawn on the chart from which the pressure and the volume at any point can be ascertained. Thus, if through the admission of heat from P to P_1 the volume remains constant, the line P P_1 forms part of a constant volume line; or, again, if the pressure were to remain constant, it would form part of a constant pressure line. These same remarks apply to line P_2 P_3 followed during the abstraction of heat usually known as the exhaust period.

If both P P_1 and P_2 P_3 are constant volume lines, the cycle of operation is known as a constant volume cycle, and it will be further observed that since P P_2 and P_1 P_2 are vertical lines, obviously, from the construction of the chart there will be no change of heat during those parts of the cycle. These lines are known as adiabatics. The cycle just described is known as the constant volume cycle, and is that followed by a gas engine or by an explosion oil engine working on the Otto cycle, or, more strictly, on the Beau-de-Rochas cycle.

If both P P_1 and P_2 P_3 are constant pressure lines, the cycle of operation becomes a constant pressure cycle. No engine to-day working on this cycle is on the market. If P P_1 is a constant pressure line, and P_2 P_3 is a constant volume line, the cycle of operations is that followed by the Diesel engine. If P P_1 and P_2 P_3 are constant temperature lines, the cycle is known as a constant temperature cycle, and is also called the Carnot cycle. No practical engine can work on this cycle.

Table I. has been prepared to give some idea of the theoretical thermal efficiencies obtainable under various conditions.

Table I.

Description of Plant.	Abstract Temperatures. Theoretical °C.		Thermal Efficiency.			
	Highest.	Lowest.	Theoretical Cycle.	Carnot Cycle.	Actual Plant from per B.H.P.	Actual Plant to per B.H.P.
Non-condensing steam plant	458	373	17·8	18·2	4	8
Condensing steam plant superheated	561	310	31·0	45·0	10	15
Gas engine and producer	2100	370	47·0	82·5	16	24
Oil engine	2000	370	40·0	82·0	16	19
Diesel engine	2000	370	56·0	82·0	26	32

As in the case of water engines, only a fraction of the theoretical possibilities are practically realisable, because various losses have to be deducted; these losses can only be minimised, they cannot entirely be got rid of. That is to say, the amount of heat practically utilised as work is less than that theoretically utilisable, and the ratio of the lesser amount to that supplied is called the actual thermal efficiency of the engine.

The ratio between the actual thermal efficiency of an engine and the theoretical thermal efficiency of its cycle is known as the "efficiency ratio," and substantially may be taken as follows, for certain typical heat engines: Non-condensing steam engines using saturated steam, 60 to 80 per cent.; condensing steam engine, using superheated steam, 50 to 70 per cent.; gas engines, 80 to 88 per cent.; oil engines (explosion type) and Diesel engines, about 75 per cent.

The actual thermal efficiencies of various engines referred to in Table I. have been deduced from the above, and in the figures given under that heading allowance has also been made in the case of steam engines for boiler losses, &c., and for producer losses in the case of gas engines. It has already been stated that between given values of the highest and lowest temperatures occurring in the cycle, the Carnot cycle has the greatest possible thermal efficiency, and, for the sake of comparison, this thermal efficiency has been added to the table for each item.

As a further comparison, heat chart diagrams of some of the engines entered in the table are given in Fig. 6 on the assumption that the amount of heat introduced is the same in all cases, and this being so, the areas enclosed in thick lines, representing the possible conversion into work, are in proportion to the theoretical thermal efficiencies. The various losses are deducted, and the remainder indicated by the areas shaded by dots are proportional to the actual thermal efficiencies.

The great thermal efficiency of the Carnot cycle has been a considerable temptation to inventors, forgetful of the fact that, apart from other difficulties, such an engine would have a very small mean pressure in the cylinder, and therefore would require enormous pistons and cylinders. However, it was from an attempt of this nature on the part of Dr. Diesel that he gradually evolved the oil engine which bears his name. In 1892 he published a book which was translated into English by Bryan Donkin, jun., entitled, "Theory and Construction of a Rational Heat Motor," in which he argues that if combustion is carried on in a cylinder at constant temperature, theoretically a slightly higher efficiency than that of the Carnot cycle can be obtained, because a less weight of the fluid has to be compressed than has to be expanded, owing to the addition of fuel being made after compression. He appears, however, to have forgotten that the abstraction of heat in the case he considered could not be effected at constant temperature, or at anyrate he assumed that it could so be extracted. The cycle he then proposed was, therefore, unrealisable; moreover, it is not at present practically possible so to regulate the oil admission as to obtain a constant temperature, but rather an approximately constant pressure is obtained. Hence, as a

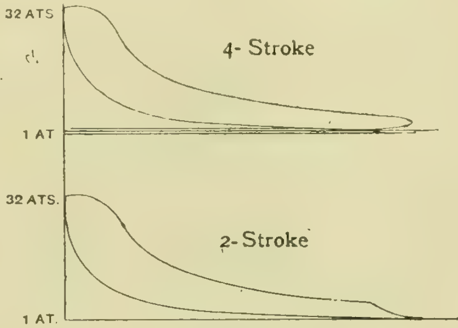


Fig. 8.

practical matter, as already stated, the Diesel oil engine works on a constant-pressure volume cycle, the thermal efficiency of which is given in Fig. 6, whereas, under the same range of temperatures Herr Diesel expected to get a thermal efficiency of 0·855, corresponding to a coal consumption of 0·25lbs. per horse-power, for it should be mentioned that the first trials were made with pulverised coal and not with oil, and designs for an engine working in this manner are given in the book referred to.

In the ordinary gas engine or explosion oil engine the heat is introduced to the working fluid theoretically at constant volume, because, the mixture being exploded, the combustion is complete before the piston moves from the dead point. Practically, however, a considerable portion is added at increasing volume, because the explosion is not instantaneous, and this is a cause of loss. In the Diesel engine the oil is introduced comparatively gradually, and at such a rate that the pressure remains nearly constant. The indicator diagram will, therefore, theoretically have a flat top. Practically, only an approximation to a flat top is obtained, as shown in Fig. 7, which gives both a theoretical and a practical diagram. On this figure are also shown theoretical and practical indicator diagrams of an ordinary gas engine for the sake of comparison. These indicator diagrams illustrate the fundamental difference between the Diesel and the Otto engines. In the Diesel engine the continued combustion of the oil is achieved, as already mentioned, by pulverising it, and injecting it in this state into the cylinder by means of an air blast, and owing to previous compression up to about 32 atmospheres (500lbs. per square inch), the air in the cylinder is at a sufficiently high temperature to ignite the oil.

Attention is called to the difference in the compression reached, as shown in these two diagrams. In the case of the Otto engine, the explosive charge is compressed about 130lbs. per square inch gauge. A greater pressure is not practically

permissible for fear of pre-ignition. In fact, this is about the highest compression used in gas engines working with producer gas; with town gas it is less, and with ordinary oil or petrol engines the pressure has to be still further reduced, namely, to about 80lbs. per square inch, and it is this low compression which prevents this latter type of engine having a high thermal efficiency.

In the Diesel engine, however, the combustible matter is added at the top of the stroke on the turn of the piston. Only air is compressed, and therefore pre-ignition, in the ordinary sense, is not to be feared. Consequently, much higher compressions are possible, which is the real cause of the great thermal efficiency of the Diesel engine. This high compression raises the temperature of the air to about 700° C., so that the temperature in the cylinder at the moment the oil is injected is sufficient to cause its ignition, thus no special means of ignition, such as the electric spark or the hot tube required by the ordinary gas engine, are needed. In the semi-Diesel engine, as already stated, the compression of pure air is considerably less, and the pulverised fuel is injected into a hot bulb, which causes it to ignite. The heat introduced into the working substance partially at constant volume and partially at constant pressure.

This immunity from pre-ignition of the Diesel and semi-Diesel engines may be regarded as a great advantage these types have over the ordinary gas or oil engine, because it may be safely said that a large proportion of the troubles which have arisen in connection with large gas engines are due to pre-ignition.

The cycle followed by the Diesel engine can now be stated completely, and is illustrated diagrammatically in Figs. 7 and 8. A charge of pure air is sucked into the cylinder through the air valve, and on the return stroke this air is compressed to a pressure of from 450lbs. to 500lbs. per square inch, so that the ratio of compression needed is about 13 to 1 (as against 6 to 1 for the ordinary gas engine), and the clearance in the cylinder is arranged accordingly. At from 1° to 2° before the end of the stroke the fuel valve opens, and the charge of oil is pulverised by means of an air blast and a special device to be described in detail later, and is injected into the cylinder. The requisite amount of oil, determined by the action of the governor, is forced into a space above the fuel valve by means of a fuel pump. The pressure of the air blast varies from 750lbs. to 900lbs. per square inch according to the proportion of the full load the engine is working at, and an air compressor has to be provided for supplying this high-pressure air.

After combustion, expansion of the products of combustion takes place until the exhaust valve opens, which occurs at about 0·9 of the stroke, and then the pressure in the cylinder suddenly drops to atmosphere. Finally, the piston on its return stroke sweeps out the remaining products of combustion, and the cycle is complete. It will be seen that four strokes, namely, two up and two down (in a vertical engine), are needed for one complete cycle, and the engine described therefore works on a four-stroke cycle, corresponding in this respect to the Otto or Beau de Rochas cycle of a gas engine.

Up to the present the greater number of Diesel engines have been designed on the four-stroke cycle. Arrangements can, however, be made to introduce a blast of air into the cylinder at the moment the exhaust valve opens, and thus, not only will the products of combustion be swept out, but also the cylinder will be filled with pure air. The cylinder is then in the same condition as on the second up-stroke of the four-cycle type, that is to say, pure air is compressed, and hence fuel can be injected at the end of this stroke. A combustion stroke will therefore take place at each down stroke, and the engine then works on a two-stroke cycle. In this way double the power can be obtained from a given cylinder. This type of Diesel engine is now being rapidly developed, and eventually will probably be the only type used for large marine engines.

Gas engines also work on the two-stroke, or Clerk cycle, the products of combustion being scavenged just before the explosive mixture is introduced into the cylinder. In this case the difficulty arises that if the scavenge is too powerful, unburned gas will be blown into the exhaust and lost, because it has to be admitted into the cylinder immediately after the scavenging air and before the exhaust ports are closed (except in the case of the Oechelhauser engine). If, however, the scavenge is reduced, a portion of the exhaust will be left in the cylinder, thus reducing the weight of explosive charge. These difficulties do not occur with the Diesel engine, because the fuel is not admitted until later, and within reason any amount of air can be blown through the cylinder to clear out completely the products of combustion. Hence the Diesel engine is essentially adapted for a two-stroke engine.

The indicator diagram of the two-stroke engine is somewhat different from that of the four-stroke, and to illustrate this difference average indicator diagrams of a two-stroke and of a four-stroke engine are given in Fig. 8.

Dugald Clerk, in 1887, built an engine using coal gas which followed the Diesel cycle, and which he called a "flame" engine. The air was alone compressed in the cylinder, the gas being compressed separately by a side pump forced into the engine cylinder through a series of gas jets, and ignited exactly as it entered. This engine worked very well, but the mean pressures obtained were too low, because the compression pressure was too low, namely, only 90lbs. per square inch.

(To be continued.)

The Greatest Ocean Depth.—According to the "Geographical Journal," an ocean depth surpassing all previous records has been sounded by the German survey ship "Planet" 40 nautical miles east of Northern Mindanao. The depth obtained was 9,780 metres, or 5,348 fathoms, and the sounding was obtained under conditions which permit the fullest confidence in its accuracy, while a determination of bottom temperature and a sample of the sea-bottom at the spot were also secured. The greatest depth previously known was that found by the American ship "Nero" near Guam in 1899, which was fixed at 5,268 fathoms.

The "Synchron" Artificial Respiration Apparatus.—There has, says the "Great Western Railway Magazine," been installed at the Park Royal Generating Station the "Synchron" apparatus for performing artificial respiration for the restoration of animation in severe cases of electric shock. The "Synchron" has been patented by Dr. K. A. Fries, of Stockholm, and consists of a wooden shield, with headpiece, attached to which is a light steel frame with crossbar, adjustable by automatic clamps for any length of arm. A canvas girdle or band for compressing the chest is provided with eyelets for regulating it to any desired size. Artificial respiration is performed by moving the frame upwards and downwards. It is claimed that the apparatus can be brought into use in 10 seconds.

Institution of Civil Engineers Awards.—The Council of the Institution of Civil Engineers have made the following further awards for papers read during the session 1911-1912: A Watt Gold Medal to Prof. W. H. Burr (New York), and the Crampton Prize to Prof. R. J. Durley (Montreal) They have also awarded the following Telford Premiums for papers published in the Proceedings without discussion during the same session: To Messrs. Paul Seurot (New York), David Anderson and Harry Cunningham (London), S. P. Smith, D.Sc. (Birmingham), E. G. Rivers, I.S.O. (Richmond), and E. H. Morris (Manchester), and Prof. A. H. Gibson, D.Sc. (Dundee). The Howard Quinquennial Prize for 1912 has been awarded to Mr. J. H. Derby (Sheffield), in recognition of improvement introduced by him in iron and steel production, and the Indian Premium for 1912 to Mr. H. H. G. Mitchell (Madras). The Council have made the following awards in respect of students' papers read during the session 1911-1912: The "James Forrest" Medal and a Miller Prize to Mr. E. P. Currall, B.Sc. (Birmingham); and Miller Prizes to Messrs. J. H. Taylor (Glasgow), W. P. Warlow, B.Sc. (Bristol), G. Ingram (London), E. F. Hunt, B.E. (London), H. J. F. Gourley, B.E. (London), H. G. Hoskings (London), E. A. Cross, B. Sc. (Birmingham), and J. and W. Legg (London) ; and the "James Prescott Joule" Medal to Mr. V. E. Green (Birmingham).

THE TRAINING OF ENGINEERS.*

BY CHARLES DAY, WH.S., M.I.M.E.

The past year has been one of considerable unrest in the industrial world, and as such a condition greatly increases the difficulties which arise in the conduct of trade, it is necessary that those intimately connected with the various trades carefully consider whether anything can be done to prevent this state of unrest from spreading or from increasing in intensity. It would not be appropriate on this occasion for me to speak on questions of wages, but I think it is appropriate to consider the conditions under which youths enter into, and work in the engineering trade, as these conditions influence the views formed at a susceptible period of life. If a youth can clearly see that his employers are giving him every reasonable opportunity to prepare himself for the higher positions of the trade, it is reasonable to suppose that such a youth is much less likely to develop into the type of young man who thinks that employers are his natural enemy, and are striving to keep him down: a view which, unfortunately, seems to be held by some.

In connection with the engineering trade, I think it is possible to so arrange the conditions of employment for apprentices that all may have a reasonable chance of fitting themselves for advancement, and this without making the conduct of business unduly difficult. To put this into practical form, I venture to outline a set of conditions under which apprentices might be employed:—

1. All apprentices to start on level terms, *i.e.*, no special privileges to be arranged in advance for any apprentice, either in regard to the number of departments he is allowed to work in, or in regard to his treatment whilst in those departments.

2. A certain proportion of the apprentices to be given a change of department, providing, of course, the conditions of trade allow of it, such apprentices to be selected from those who, by attention at evening classes, have shown a desire to improve themselves and who, by good results at those classes, have shown satisfactory mental capacity and persistence. Satisfactory work in the shops should also be a condition. By these means the capable and ambitious apprentices will obtain wider and more valuable training than those whose characteristics do not fit them for advancement, and the selection is almost automatically made by the apprentices themselves.

With a scheme of this kind, those who by their own want of effort limit their experience to one department of a works can, of course, only blame themselves if, at a later date, they see that this narrowness of training and inattention to the theoretical side prevents them from advancing to higher positions. It may be desirable to carry the scheme still further and provide that some of the most successful apprentices be given the full-day course at a technical school, or at least be given the opportunity to get it. In the Manchester district an intermediate step can be taken by utilising the apprentice course at the technical school, a course which is proving of distinct value. In this course apprentice engineers attend at the school each Monday during the winter session, the remaining working days being devoted to their usual employment, with their evenings free for home-work. The course is designed to extend over two years, but naturally employers should take care that any apprentice who does not take proper advantage of the first year is displaced when the selection is made for the following year.

The advanced theoretical training of engineers is a thorny subject and full of difficulties, for it must be remembered that though a high theoretical training is necessary for some positions, the number of such positions is comparatively small. What kind of education is then desirable for the employés of an engineering works? In the case of many workmen we merely want manual skill combined with steadiness and attention to work, but in many cases, as, for instance, in the case of an erector, who is sent out to erect and set to work various kinds of machinery, a sufficient education is required to enable him to write a clear report, and in addition it is often desirable for him to have some knowledge of the basis principles connected with the machinery he is engaged upon. As an instance of the advantage of a knowledge of such principles I might quote the case of an erector who, on starting up a condensing plant connected with a steam turbine, finds that though he expected to get 28½in. vacuum he only gets 27in., and who then spends a lot of time hunting round for defective valves and pistons, or for air leakages, whereas had he known the elementary laws in regard to saturated steam he would have at once recognised that the defective vacuum was due merely to an insufficient supply of water causing the hot-well temperature to be so high as to render a 28½in. vacuum quite impossible. For many workmen, and particularly for patternmakers, the capacity to read drawings very thoroughly is essential.

For foremen the qualities required vary very much. For some they are such as mentioned for an erector, but in all cases a foreman should be familiar with the tiniest details of his department, and must have a very considerable knowledge of human nature so as to enable him to handle those under him without raising unnecessary friction. A foreman in a machine shop does not require to be a mathematician or to have a deep knowledge of, say, the theory of heat, but he should know the elements of mechanics and a good deal about the various machine tools available, also should have a knowledge of modern developments connected therewith. Incidentally, I may say here that there is scope for a scheme which would enable foremen and others to see frequently new machine tools at work and get data as to the time occupied in doing work with which they are familiar. Possibly a scheme could be devised whereby the machine shop at the technical school could be utilised for this purpose.

In the case of draughtsmen there is no doubt that technical education needs to be carried to a further degree, and in any works it is desirable that a few of the draughtsmen be men with advanced theoretical attainments, so that special problems can be investigated and worked out.

The educational qualifications for managers and employers are very variable, depending largely on the class of work engaged upon, but a very sound training in first principles and in their application is a vital necessity to enable the probable effect of new developments to be gauged. Also it is very desirable for men in these positions to know what is going on in other branches of engineering, as it frequently happens that a troublesome new problem in one business has been dealt with and overcome years ago in another business; thus a fairly wide outlook of what has taken place in engineering is of special advantage.

For every different position in different works a different schedule of requirements might be made, but if this was done I feel sure that the number of positions for which high theoretical attainments are essential, or are even the principal factor, would be comparatively small, though those positions would be important ones. In bringing out this point it is far from my intention to deprecate technical education, for I intend to show its value. At the same time it must be remembered that there is a substantial difference between a broad technical education and high theoretical attainments. It, however, seems better to face the position boldly and, further than this, an appreciation of this fact may encourage those whose circumstances do not enable them to acquire high theoretical attainments to realise that there are very many important positions open to them, for though scholastic training can help, and help greatly, it will never be so important as natural qualities. At present, however, I do not propose to say anything more about natural qualities, but to consider only how education can help an engineer.

A generation ago an apprentice in an engineering shop probably saw in that one shop a great variety of mechanical engineering work. To-day he most probably only sees one branch, or even only a sub-branch. For instance, he may work in a shop where lathes only are built, and thus, though engaged on tool-work, he may only see one small section of this branch of mechanical engineering. Similarly, he may work at a shop where only small petrol engines are made, and thus only see that section of the internal-combustion engine trade. Such intense specialisation has no doubt great advantages, and will not only continue, but will even become more prevalent in the future. Nevertheless, it has the great disadvantage of narrowing the outlook of those so engaged. A young man may widen his training by later on changing

* Inaugural address by the President, presented before the Manchester Association of Engineers, October 12th, 1912.

from shop to shop, but in doing this he loses opportunities of advancement in the line he started on, as in a shop devoted to a speciality the first step up from the position of ordinary workman will in the great majority of cases be given to one with special experience in that particular line. This narrowness can be overcome to a considerable degree by suitable training in a technical school or college which is equipped with a really good mechanical laboratory, as the student then sees and works upon a wide variety of modern machinery. Hence a very important feature of a course of training at a well-equipped technical college lies in the wider outlook which results from seeing examples of many phases of engineering productivity, and of receiving explanations of their construction and action by teachers who are able to show how the first principles taught in the lecture-rooms are applied in practice. It is from this point of view that the extensive and varied lot of machinery in the engineering laboratories has much value.

I would point out here also that there is very much to be learned in that portion of the laboratories which deals with the testing of materials, and that many lessons can be readily learned there which can hardly be learned otherwise. A course of study at a technical school or college, together with the work in the laboratories, should therefore give a wider outlook on engineering than it is possible for a youth to have who has spent his whole time in a works devoted to one or even to a few specialities.

It is perhaps well to mention here that much which is called theoretical is really intensely practical, being the reduction to words of accumulated practical experience. Numerous instances could be quoted of engineering problems solved and understood only after years of practical effort, and thus much that is taught in the schools is the boiling down to a compact form of lessons learned by past experience. Were it not for this each generation would to a large extent have to learn by slow experience the lessons of previous generations. Fortunately this is avoided by the teaching in our engineering schools, by books, by technical literature, and, though mentioned last, by no means least, by the papers and discussions before engineering associations.

While considering the matter of training of engineers, it is not sufficient for us to think only of the requirements of the particular business engaged upon at the moment, but it must be borne in mind that new inventions and great developments will have to be faced. Frequently such new inventions involve quite new lines of thought in their application, and men whose training has been in a narrow groove will probably be found quite unprepared (I do not say unfit) to cope with the new problems, or even to appreciate them. A good general technical training undoubtedly forms a better basis for dealing with entirely new problems than does a highly specialised one, and it makes men more disposed to watch new inventions and developments closely.

It is, then, a matter of importance for us to see that a sufficient proportion of our engineers receive a general technical training, and I would suggest that all engineering firms who do not at present assist or grant time to any of their apprentices to acquire such training might consider the desirability of doing so to one or more of those apprentices who have already shown capacity. For the reasons mentioned at the commencement of this address, I feel confident that such a policy must tend to create a better feeling between employé and employer.

From the foregoing notes it would appear that the technical education required for the different positions in engineering may be roughly graded as follows: (*a*) A grounding in the general basis principles underlying engineering work, combined with facility in reading drawings. (*b*) A sound training in these same principles, together with a knowledge of their application in different branches of engineering, and a working knowledge of elementary mathematics. (*c*) The same as (*b*), but with a more advanced knowledge of mathematics and of problems involving mathematics.

I certainly believe that to-day, and even more so in the future, every engineering apprentice who desires to rise at all must at least attain standard (*a*). Those who neglect to reach this standard practically decide for themselves their future positions. If attention at evening classes can be followed by a course such as the Apprentice Course, already mentioned, so much the better. After that, if facilities can be given for a picked few from each works to take a two or three years' full-day course, this would, I believe, be of distinct advantage not only to those apprentices but to the trade of the country.

One point I would add, viz., that attention to evening classes should not stop at the age of 21, and particularly so with those who have only been able to follow course (*a*), but opportunities should be taken to attend laboratories and special lectures, and it is to be remembered that the laboratories, as well as advanced lecture courses, are in most technical schools or colleges available to evening students, so that all who are determined to take advantage of them can do so.

The problem of employment for young men who have been trained at colleges might be briefly considered here. Most employers and managers have often to consider applications for employment from young men who have taken a course of training at a technical school or college, and who may have done exceedingly well, but who desire to get to practical work. It is by no means easy to deal with this problem, as advanced theoretical training, though of great value in the higher positions already mentioned, is not of much value in the lower positions. In fact, there is some danger that the college life and training has the effect of spoiling a young man for the comparatively dull and arduous work of an engineering shop, where each person is judged from a purely productive or money-earning point of view rather than from what it may be possible some years later to make of him.

In a few shops young men from the colleges can be at once utilised to advantage in testing or experimental work, but in most mechanical engineering shops these openings are relatively few, and a start must be made at the bottom of the ladder just as ordinary apprentices. The probability of this must be faced by those who take the college course before the practical work, and I might add that a young man leaving college should more often apply for a "job" in a workshop rather than, as he so often writes, "for a position where his training will be of value."

ROLLING-MILL PRACTICE IN THE UNITED STATES.*

BY J. PUPPE, D.ING. (BRESLAU).

THE development of the iron industry of North America, which has achieved as remarkable a record of progress in the last decade as in the preceding one, and the improved methods of working, especially in respect of rolling-mill practice, still form an object-lesson of paramount interest to European iron manufacturers. Early in 1911 it was the author's privilege to visit the majority of those ironworks of the United States where typical American rolling-mill practice is followed, for the purpose of studying the latest methods and improvements. In the diagram, Fig. 1. figures are given of the production of rails, structural iron, wire rod, and blackplates for the years 1880-1911.

Cogging Mills.—During the 'nineties cogging mills in the United States were almost exclusively constructed on the 3-high system, but since the introduction of the 4in. billet the 2-high reversing mill has been practically universally adopted. The 3-high mill was brought to a remarkable state of perfection by the brothers John and George Fritz, and there are still a number of such mills at work, especially where one section only, or at all events a very limited number of sections, is rolled continuously. In rolling 4in. billets, however, the great length of the pieces made it impracticable to use the 3-high mill, as the lifting tables could not be made sufficiently long to accommodate them, and the 2-high reversing mill had to take its place.

In contradistinction to German practice, where the cogging mill forms the link between the steelworks and the mills for all sections down to 4in. square and less, also for slabs and flats, in the United States it forms an integral part of a particular rolling-mill train, and performs the roughing down to a certain section only. Typical instances of this practice may be seen at Lackawanna and at Gary. At the Lackawanna works the cogging rolls serve for roughing down the ingots for the billet mill, whereas the heavy rail mill has several stands of cogging rolls for that mill alone. At Gary,

* Abstract of paper read before the Iron and Steel Institute, October, 1912.

where the cogging rolls for the rail and billet mills consist of separate 2-high sets followed by a 3-high set, the arrangement has been planned not only with the object of getting the largest possible output, but has also been determined by the method chosen for driving the trains. In very rare instances the cogging mill supplies the plate mill with slabs, the practice at the works of the Youngstown Sheet and Tube Company affording one such example. In all other mills visited where slabs are rolled, a type of rolling-mill entirely unknown to the author has been developed, namely, the slabbing mill, which may be described as a universal slab and roughing mill.

The cogging mills are generally of quite small diameter, the pitch circle of the pinions measuring, as a rule, 35in. to 40in. or 42in., the roll diameter being about 3in. to 5in. smaller. Latterly a 34in. diam. has become the standard for such mills. On this account the roll length is much shorter than in Europe, generally not exceeding 6ft. 6in., as compared with 9ft. 4in. in German mills. The arrangement of grooves is also different, the first groove not being at the side but in the centre, and consisting really of the smooth surface of the roll, which is kept at its full diameter at that part. In Figs. 2 and 3 is shown the draughting of the rolls at the Lackawanna works and the Youngstown Sheet and Tube Company's works. The production of sections varying greatly in size is attained by giving a very high adjustment, in some cases three times as great as in European practice, where 40in. is about the maximum. The same pressure can be applied to the rolls, while, owing to the small diameter, less power is required for driving. The wobbler connecting the upper roll with the pinion must be of a length corresponding to the increased height of rise, and in some instances it was found to measure 22ft., and in another 17ft., long. With such mills remarkably high outputs can be obtained. For instance, the cogging mill at Lackawanna turns out 500 tons in a single shift, the 40in. mill at Duquesne averages 600 tons per shift, and the 38in. mill at the same works can turn out 1,300 tons per shift. These quantities, of course, fluctuate considerably, but the facility with which such large outputs are obtained is explained by the fact that the ingots are not rolled to anything like the same length as in Europe, the elongation being generally five to six times, and at most seven times. The rolling period is consequently much shorter. On timing the operations at random, the author noted that nine passes were made in 40 secs. and again in 47 secs., seven passes in 41 secs. to 48 secs., and on other occasions the times were remarkably short. In the matter of rapid passes the 3-high mills show great superiority, as might be expected.

Another striking difference between German and American practice is the rate of diminution of the draught of cogging rolls. Whereas in Germany a reduction of 14 per cent. is hardly ever exceeded, and with harder material an average of 11 to 12 per cent. reduction is the rule, the reduction in the draught from one groove to the next often amounts to 20 per cent. in American practice. The roughing rolls of the rail mill at Lackawanna even give an average reduction of 24 per cent. per pass in the first six passes. How far the structure and quality of the material suffer in the case of rails is a question which will be discussed further on. The final section of the piece after passing the cogging rolls is, of course, larger than in German practice, and varies generally from 6in. to 8in. square. The shortness of the rolling period is further accounted for by the manner of controlling the auxiliary engines, which now very generally consist of electric motors. The controllers are operated with very short levers with short ranges, and there are only three notches, "Stop," "Forwards," "Backwards," with no intermediate steps.

The rolling-down operation is mostly performed in the same way as in Germany, the piece being continually turned over and the section retaining its square form. Here and there, however, an entirely different practice is followed. For instance, in the 35in. mill of the National Tube Company the ingot is rolled out flat in nine passes through the widest groove to a thickness of 4in. It is then turned on edge and put through the 4in. groove, then two passes are again made through the 12in. groove, one pass through the 5in. groove, and finally one through the 7in. groove. On account of its great width, after the first nine passes it requires to be guided into the next groove and held with hydraulically operated guides. This method has been introduced at one mill in Germany, but it has considerable disadvantages—first, the difficulty of putting the wide piece through the rolls on edge; and, secondly, there is a tendency to crack at the corners, owing to the material being subjected for so long in one direction to the roll pressure.

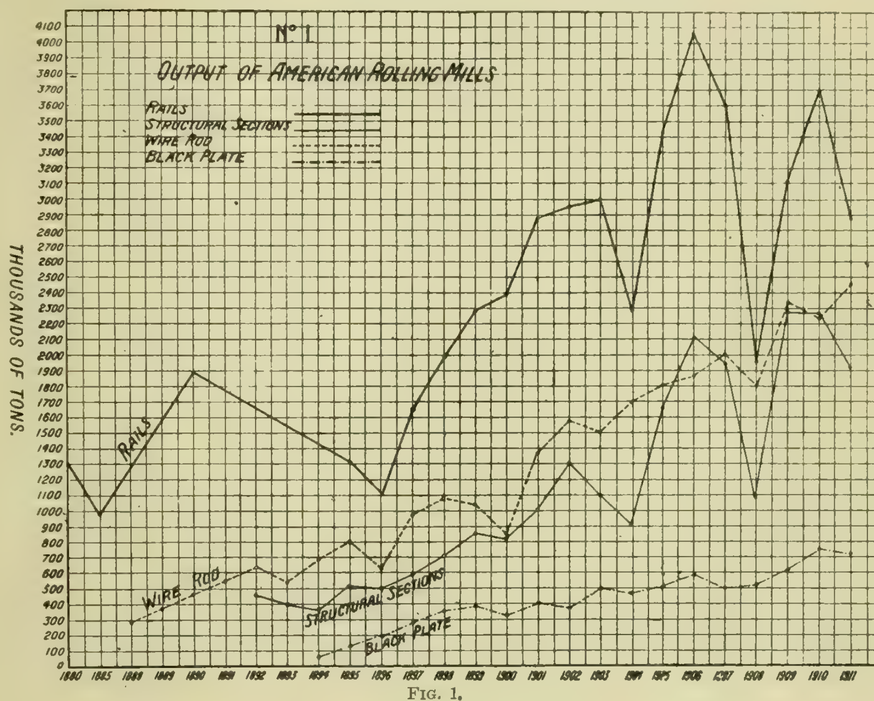


FIG. 1.

Summarising all these facts, it appears that American cogging mills differ considerably from German ones both in point of construction and design and also in the method of working, but that the high rate of production is chiefly rendered possible by the very much simpler plan of rolling, which consists in rolling to larger sections, thus shortening the rolling period, and by the rapid and accurate handling of the auxiliary engines. The ingots are almost always heated in soaking pits which can take several ingots at one time. This is usual partly on account of the cheapness of fuel, and partly because the service of the mills being almost entirely automatic the ingots must be of a uniform temperature throughout.

Billet Mills.—In proportion to the lightness of the finished product is the difficulty of preparing pieces of a suitable initial section. The use of a section rolled from a large ingot, as represented by the billet, dates in America from the year 1880. At first billets with a section of 4in. by 4in. were produced in the roughing rolls, and this practice led to the abandonment of 3-high mills in favour of the 2-high reversing type, on account of the unsuitability of the lifting tables for dealing with pieces of great length. Later the practice was further developed by the rolling of billets of a still smaller section, partly with a view of relieving the roughing rolls and partly for the purpose of lightening the work of the finishing rolls; also it was an advantage to roll down to as small a section as possible before reheating the billet, which, in any case, was necessary before sending it to the finishing mill. The economy of having a set of rolls intermediate between the roughing rolls and finishing mill is apparent where there is a large market as in America, provided it is technically possible to construct a mill capable of taking the whole production of the roughing mills and rolling it down in the same heat. It would be economically possible to roll 4in. billets in the roughing rolls, but since these

are designed for definite sections of large size their whole object would be lost if it were attempted to roll billets of any size under 4in. square.

It is noteworthy that at first the endeavour was to roll from as large a section as possible direct down to the finished shape in one heat, and the introduction of the 4in. billet marked a great advance, as compared with the $1\frac{1}{2}$in. billet, in the production of which two heats were required. Latterly the tendency is to revert to the billet of small section, the weight being kept up by making them very long. The Morgan mills, which work up $1\frac{1}{2}$in. billets, 30ft. long, are now in great favour.

The semi-products of the roughing rolls, however, generally average about 6in. to 8in. square, and, for the production of small profiles and wire rods, these are rolled down into billets varying from 4in. to $1\frac{1}{2}$in. square, for which, and

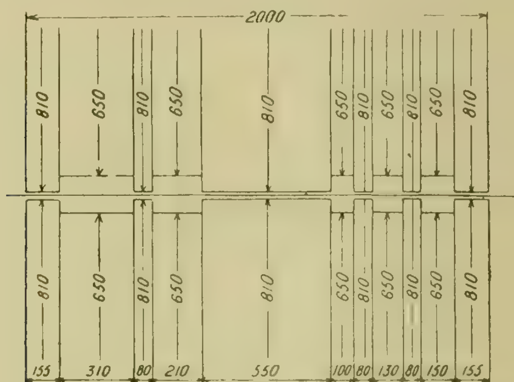


FIG. 2.

also for flat bars, continuous billet and bar mills of eight to ten stands are almost always provided. Where the output is too small to make it worth while to install a billet mill, the ingot is rolled down further in the roughing rolls, as in the 2-high reversing mill of the Tack Company at Grand Crossing, where $1\frac{3}{4}$in. square billets are rolled in the roughing rolls. To expedite the work, however, the piece after being reduced to 4in. square is sent back over the roll without reversing, the engine meantime running away.

The only non-continuous billet mill is the 3-high stand with 23in. rolls of the American Steel and Wire Company at Newburgh, which rolls down pieces of 7in. by 8in. into 4in. billets in seven passes. Also the billet and bar mills of the Carnegie Steel Company at Duquesne and Ohio are not continuous mills in the usual sense, but are converted rail mills, which, however, are very suitable for the production of large semi-products. A set of continuous rolls has been added in which billets of the smallest section can be rolled.

The billet and bar mill at Duquesne takes the material coming from the 38in. 2-high mill in front and from the 28in. 3-high mill, and rolls it down simultaneously into bars and billets or into fishplates and billets, the method being as follows: The first piece, after one pass through the 21in. 3-high billet mill, is cut straight into thickish billets. The second piece, after one pass in the first stand, is also cut into billets, which each receive one pass in the second stand and are then taken direct to the continuous mill, where they are rolled down into thin billets. The third piece is also cut up after one pass through the first stand, the resulting billets being then each passed once through the five following stands, and finished into fishplates or bars.

The converted rail mill at Ohio is also very suitable for rolling billets, since its construction as a double 2-high reversing mill gives it great adaptability to cope with the large output of the 43in. 3-high roughing rolls. The production of this whole mill amounts to 3,500 tons per 24 hours. The appliance for pushing the billets sideways is ingenious. The pusher works very rapidly, and in returning is lifted clear so as to allow the next billet to run under it.

The roll diameter in the continuous mills is comparatively small, being seldom above 18in., and in some mills not more than 14in. Considerably less power is required, but this is more than compensated for by the losses in the trains of gearing. The small diameter entails a short length of roll, with only few grooves, which makes possible the use of very high pressures with safety. The average reduction of draught in continuous mills is always above 20 per cent., whereas the average reduction in the 23in. 3-high mill of the American Steel and Wire Company is only about 16 per cent. The draughting is usually designed with the aim of reducing to a minimum or avoiding altogether the turning and up-siding of the piece between two stands.

The draughting for rolling bars is almost always designed to avoid up-siding. All the grooves are flat, and by the selection of a correct initial section the desired width is obtained in the final closed pass, sometimes also by the use of vertical rolls behind the last stand. The two last passes of the bars are in such cases made through smooth rolls. The output of the continuous billet and bar mills corresponds to that of the roughing mill in front. At Gary the production is 300 tons per hour of 4in. billets and 150 tons of $1\frac{3}{4}$in. billets. At Lackawanna the output is 70 to 80 tons per hour, but even that would be an unusual achievement in Germany. These results are obtained by driving the last stand at a comparatively high speed, 90 revs. to 200 revs. per minute, the first stand running at 9 revs. to 12 revs. On timing the speed of working, the author found that the time from the entering of the roughed-down ingot between the rolls of the first stand and the entering of it at the last stand was half a minute, and the rolling time of a whole ingot of $2\frac{1}{2}$ tons and 7in. by 7in. was $2\frac{1}{2}$ minutes. At the billet mill of the Ohio works the piece went through from the first to the last stand in 28 secs., the last pair of rolls being 15in. diam., and running at a speed of 200 revs. per minute. The smallest billet section is $1\frac{1}{2}$in., and 8in. is the uniform width for bars.

It is the almost invariable practice to cut both billets and bars with an electrically operated flying shears. They are cut into pieces of definite length, and conveyed away at once by the live rollers behind the shears. The cooling proceeds in much the same way as here. At the American Sheet and Tinplate Company's works, however, a cooling drum is installed, measuring 95ft. long and 8ft. 6in. diam. This apparatus revolves very slowly and lifts the bars from the roller table of the shears and deposits them on the hot bed roller table, the bars cooling down all the time that they are being slowly carried round on the drum.

Rail Mills.—In 1878 there were 11 works at which rails were rolled, the yearly output being 34,000 tons. In 1880 the number of works was the same, but the production had increased to 800,000 tons. At the present time, 32 years later, there are 14 rail-rolling mills, with a yearly output of about 3,000,000 tons. As the rate of production increased the cost naturally diminished, the greatest economy being due to labour saving. The cost of labour per ton fell from about \$3·20 at the end of the 'eighties to \$1·65 in recent years, wages remaining at nearly the same figure.

It is of interest to study the question of rails in connection with the increase in production. When a single-rail mill, such as that at the Edgar Thomson works or at Gary, turns

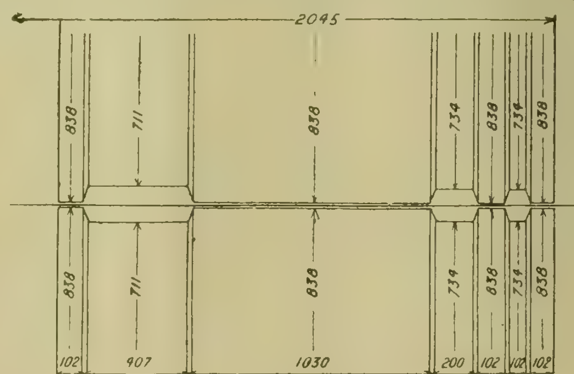


FIG. 3.

out from 3,500 to 4,000 tons in 24 hours, it is a question whether that amount of care is bestowed on the work which is desirable in view of the great importance of obtaining the requisite high quality in the finished rails. This supposition would seem to some extent to be confirmed by the fact that rail breakages in American railways are of much more frequent occurrence than in Europe, notwithstanding that for a long time past various Commissions of rail manufacturers and consumers have been investigating the causes of this trouble, and have endeavoured by various means to improve the quality. It must be admitted that the conditions of railway

service in the United States are far more severe than with us, and that the loads and speeds have been very much increased since the 'eighties. The carrying capacity of the railways has increased five times and the speeds have been nearly doubled, while the weight of rail has not been increased in proportion. The load of goods wagons has risen from 10 to 50 tons, and the weight conveyed by a freight train has gone up from 500 to 600 tons to 3,000 to 4,000 tons. The axle-load of goods locomotives is now 25 tons, as compared with 11·5 tons formerly. Speeds of 75 miles per hour have to be maintained daily between stops in order to make an average speed of 50 miles per hour. From these considerations it will be seen that the risk of breakages must have increased considerably, especially in view of the low temperatures sometimes prevailing during the winter months.

Proposals for the improvement of the structure of the metal by lowering the temperature at which the rails were finished, and a specified permissible maximum contraction have not proved a sufficient remedy in increasing the resistance to shock and jarring. In 1903 the Rail Commission of the American Society of Civil Engineers received a pronouncement from a railway engineer-in-chief as follows: "The combining of the rail-rolling mills has resulted in a continuous deterioration of the rail material, and every effort must be made to counteract this tendency." Lately a thorough inspection has been maintained at the rail mills by the authorities of 15 railway systems, with upwards of 90,000 miles of track, and throughout the day and night shifts the work in the steelworks, at the roughing mills, the rail mills, and testing machines is supervised by an engineer in each department.

The question as to whether the number of rail-breakages are due to inferior quality resulting from the rapid production on a large scale, in conjunction with the acid Bessemer process which has long held the field, or are to be attributed to the severe conditions of service, is a question which, at all events, is not yet solved. The fact is, however, noteworthy that the production of rails of special steel is now continually on the increase in the United States, and there has of late been a considerable decline in the output of acid Bessemer rails. In 1911 the production of Bessemer rails was only 1,156,852 tons, as compared with 1,948,586 tons in 1910, or a reduction of 40 per cent. On the other hand, the production of open-hearth rails in 1909 was 121 per cent. greater than in the preceding year (in 1909, 1,276,056 tons, and in 1908, 576,381 tons). In the same manner the production of special steel rails rose from 51,313 tons to 203,831 tons, or about 300 per cent. between 1909 and 1910, and the production of titanium steel rails increased from 36,250 to 198,535 tons, or by 440 per cent. During 1908-1911, that is, three years after the first trials with titanium steel rails, 400,000 tons of such rails altogether have been laid at different times; the rails were rolled at the Lackawanna Steel Company's works, which make a speciality of them.

It is noteworthy that at the Indiana Steel Company's works at Gary, open-hearth furnaces alone have been decided upon, from which it is clear that American railway engineers prefer open-hearth to acid Bessemer steel rails. At the same time the increase in the production of open-hearth rails is also in some respects due to the increasing scarcity of suitable ores for smelting Bessemer pig.

Naturally the treatment during rolling has a particularly important influence on the rail quality. The initial and final temperatures, the cross-section and length of ingot, the proportion of initial and final section to the number of passes, the roll-draughting and the treatment of the finished rails, all play an important part. One would suppose that in the course of years a certain standard might have been adopted which would form a basis of comparison, and would permit conclusions to be drawn as to the quality of the finished product. The temperature would, of course, be the first subject of observation. In 1901 the Kennedy-Morrison process of rolling was in use at the Edgar Thomson works, which, by means of a special hot-bed, enabled the temperature of the rails to be lowered before the last pass. This would probably have but a slight effect in altering the structure or increasing the resistance to wear, considering that in the very short time allowed the cooling effect would not have penetrated uniformly to the internal metal of the rail. Moreover, the pressure in the last pass cannot be permitted in sufficient amount to influence the alteration of the structure throughout the whole section.

In the author's opinion, a better solution of the question is to be found by paying regard to the number of passes and draughting, and giving attention to the temperature and pressures throughout the whole rolling operation. The shape itself and the distribution of the material have an important bearing on the cooling conditions. The whole rolling operation, at least as far as regards temperature, might be better controlled if the specification required that the rail, after the final pass, should have a temperature corresponding to a definite longitudinal contraction, namely, for a 30ft. rail of 100lbs. per yard a contraction should be allowed of 6½in., and $\frac{1}{16}$in. less for each 5lbs. reduction of weight. Such rules would, however, only have some value if other points in connection with the construction of the rolling mill itself were taken into consideration. But the conditions of rail-rolling in the various American rolling mills differ so much, especially as regards the points which influence the final temperature, such as initial and final section, number of passes, and the relation of these to one another, that even an approximate basis of comparison is impossible, and consequently any such rules would be absolutely useless.

In illustration of some great divergences in rail-rolling practice at American rolling mills, some data have previously been published relating to the ratio of the initial and final section to the number of passes, which permit a comparison with German rail-rolling practice. The figures are taken from reports of a Commission of rail manufacturers and railway engineers, but the most important data concerning temperature and rolling period were never included, whereas a number of other particulars concerning shrinkage and amount of discard seem to the author to be of little value. To standardise the amount of discard is beside the mark, not

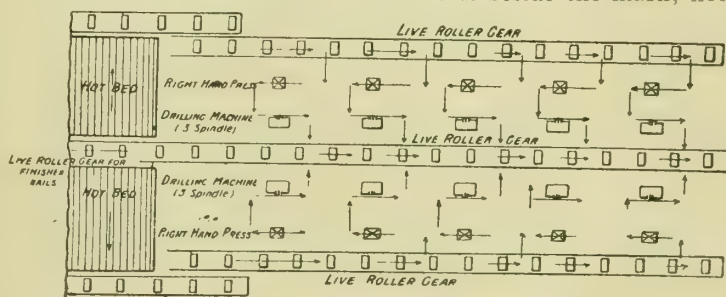


FIG. 4.

only on account of the many conditions which influence segregation, but because every ingot requires individual treatment according to the depth of the pipe, which must at all costs be cut out. If the conditions of manufacture permit that the price may be increased according to the percentage of discard, this may have the effect of a premium for the steelworks which took no interest in the improvement of its ingots or in the reduction of pipe. In German practice the elimination of piping is practicable, and can be perfectly performed; the end surfaces are milled, thus allowing any defects to become visible. Such defects are not revealed by an ordinary saw-cut alone, as practised in the United States.

It is clear, however, that it cannot be immaterial whether a comparatively hard material is rolled down to its final shape in 30 passes with a reduction of 12 per cent. in section at each pass, or in 15 passes with a 23 per cent. reduction. The finishing temperature is bound to be enormously influenced by the number of passes and the reduction of draught, thus proving the uselessness of taking the contraction as a guide for the finishing temperature; moreover, the structure of the steel, especially at the lower temperature required in the case of the harder kinds, suffers through the too severe squeezing of the metal.

In the case of nine rolling mills, their construction and arrangement are such that the requirements for a high production are fulfilled by dividing up the whole mill into a series of subsidiary trains, each of which is independently driven. This subdivision led to the wide adoption of 3-high stands, which developed further into non-reversing 2-high stands in which one pass only is made. In this connection appears also the contrast with German and English conditions, where the reversible 2-high mill is still preferred,

and of necessity, because the mills are not built with the sole object of rolling rails, but have to deal with a much wider range of material, and the capacity reached by subdividing the mills could not be fully utilised under the market conditions of Germany and England.

The disadvantages experienced in a large plant built for making a special class of material, in not being able to utilise their full capacity, may be realised from the fact that the Gary works in 1911 turned out 286,492 tons of rails, or 10 per cent. of the whole rail production of the United States, and in the previous year 443,000 tons, or 12 per cent., were manufactured. But the capacity of the Gary works is about 1,200,000 tons yearly, so that in 1910 the output was 37 per cent., and in 1911 only 24 per cent., of the total capacity. Assuming that 500 shifts were worked, the production per shift for 1910 was about 880 tons, and for 1911 about 570 tons, which, though large, is but a small proportion of the maximum capacity of 2,000 tons, and might have been attained with much simpler appliances in an ordinary German rail mill.

The number of stands varies according to the whole layout of the rolling mills and to the initial section of the ingot, and as the number of passes made in one stand is reduced the length of roll and diameter diminish. A simple subdivision of the mill into two or three 3-high stands, or two 3-high stands and a 2-high behind one another, as commonly practised in Germany, enables continuous rolling to be carried on to a certain extent, and makes an increase in output possible, provided that by exact automatic working as at the rail mill No. 1 of the Edgar Thomson works, several pieces can be rolled simultaneously.

Concerning the rail mill of the Indiana works, it is scarcely necessary to describe this here, as it has already frequently been described elsewhere. With regard to the draught, however, it may be mentioned that the ingot section is 20in. by 24in., and it is rough rolled in nine passes to about 8in. by 8in., and finished off in nine more passes without reheating. The average reduction of draught in the first nine roughing passes is 21 per cent., which must be regarded as very high; in German roughing mills 15 to 17 passes would be required for this work. It should be noted that the two first roughing stands only run at 6 revs. per minute, and the third and fourth stands at 10 revs. per minute. The shape of the grooves indicates the tendency to reach the finished profile as soon as possible, and the reductions of section are very considerable.

The rails are cut to length by several saws operated together, by means of which a sufficient degree of accuracy is reached without the necessity of milling. By the omission of milling a great economy is obtained. The only machining operations to be performed after rolling and cutting to length are the straightening and drilling of the rails. Presses are mostly used for straightening, and the roll straightening machine is rarely seen, though in common use in Germany. The drilling machines are generally fitted with three spindles. Fig. 4 shows the arrangement of the Lackawanna Steel Company's straightening plant, which requires no further explanation.

The Manchester Association of Engineers.—The 57th session of the Manchester Association of Engineers was opened on Saturday last, when the president, Mr. Chas. Day, delivered his inaugural address. This was devoted to the subject of the training of engineers, and is reproduced on another page of this issue. The following is a list of the papers to be read during the session: October 26th, "Reliability in High-lift Centrifugal Pumps," by Mr. W. E. W. Millington; November 9th, "Air Compressors," by Mr. George Barr; November 23rd, "Some Milling Experiments," by Mr. P. V. Vernon; December 14th, "Recent Developments in Curtis Steam Turbines," by Mr. R. F. Halliwell; January 11th, 1913, "Principles and their Application in the Cutting and Generation of Gear Teeth by Modern Gear-cutting Machinery," by Mr. Vincent Gartside; January 25th, "Illumination of Engineering Works"; February 15th, "Continuous Package Conveyers for Factories," by Mr. W. H. Atherton; March 1st, "The Construction and Arrangement of Buildings for Engineering Works," by Mr. H. N. Allott; March 15th, "Flying Machines," by Mr. A. V. Roe.

TOWN PLANNING FROM AN ENGINEERING ASPECT.

A PAPER on this subject was read at a meeting of the Society of Engineers by Mr. Ernest R. Matthews, Assoc.M.Inst.C.E., F.G.S., on October 7th last. The author divided his subject under two main headings: (*a*) Town planning in a residential district, and (*b*) town planning in a manufacturing area. He illustrated the former by a brief description of Bridlington's town planning scheme, and stated that one of the principal points to be considered in the preparation of a scheme was the direction, width, and method of construction of main arterial, secondary, and subsidiary streets. He suggested that these should be 75ft., 50ft., and 28ft. or 30ft. in width respectively, that they should be constructed of tar macadam with grass margins, asphalte footways, and trees, and that the buildings should be set back 25ft. in the 75ft. and 50ft. streets, and 20ft. in the subsidiary streets. He gave a description of the method of construction that he would recommend for the foundation of the streets, and for the tar macadam roadway. The author did not agree with the idea of making the foundation of the roadway in a subsidiary street less substantial than that in a wider street. He deprecated the practice of putting in heavy kerbing and flagged footways in residential districts, and thought that grass margins with asphalte footways not only effected a saving in cost, but presented a more rural and pleasing appearance. He thought that the road requirements of our by-laws were unreasonable, and resulted in houses being built with a narrow frontage and deep back, instead of a wider frontage and shallow back, which he considered far preferable.

In designing a town planning scheme it would sometimes be found necessary to allow for the widening of some of the existing roads, and also of the diversion of certain public footpaths; this had been so at Bridlington. Open spaces should be left for parks, tennis courts, bowling green, children's playground, garden enclosures, sites for public buildings, &c. The sewerage and sewage disposal of the area were matters of great importance, and the engineer must ascertain if the existing sewers and disposal works were capable of taking the drainage from the proposed area, also whether the levels permitted the area to be drained into the existing sewers, and he must devise a scheme for dealing with the storm water. The lighting of the area by means of gas or electric light was also a matter of great importance, as was that of water supply.

Town planning in a manufacturing area was very different from that of a residential area, and the points which must be considered include: (1) The position of the proposed industrial area. (2) Its proximity to railway sidings. (3) The facilities for vehicular traffic to and from this area. (4) The necessity for constructing any new roads leading to this area in a substantial manner, so that they would carry the heavy traffic likely to come upon them. (4a) The provision of roads for rapid and slow traffic. (5) The area to be occupied by workmen's dwellings. (6) The supply of electrical energy for power and lighting purposes. (7) The position for wharfage if water carriage is available. (8) Supply of water and gas. (9) Sewerage and sewage disposal. (10) Disposal of storm water. (11) Size of area. (12) Direction of prevailing winds. (13) Advisability of constructing subways under the main arterial roads. Several other points were of equally great importance from the engineer's point of view.

The New Battle-ship "Iron Duke."—There was launched on Saturday last from Portsmouth Dockyard the new battle-ship, the "Iron Duke." The vessel is one of the five armoured vessels provided for in the Navy Estimates for 1911-12, and is the first of them to be put afloat. She was laid down on January 15th. No official details of the vessel have been issued by the Admiralty. The length of the "Iron Duke" is believed to be about 600ft. overall, with 89½ft. beam, and her displacement 25,000 tons. The main armament will consist of ten 13·5in. guns of the improved type. The propelling machinery will be of the Parsons steam turbine type, arranged for four screws. The specified horse-power is about 33,000, and a speed of at least 21 knots is expected. The contractors for the machinery are Messrs. Cammell, Laird, and Co., Ltd., Birkenhead.

ROOTS' INTERNAL-COMBUSTION ENGINE.

A DESIGN of internal-combustion engine having the distribution valves of the sleeve or slide type, the invention of Mr. James D. Roots, M.I.Mech.E., 58, Avonmore Road, West Kensington, London, W., is shown in the illustrations herewith, Fig. 1 being a section of the cylinder at right angles with the crank shaft; the lower part of the engine, which is of usual construction, is not shown. Fig. 2 is a part sectional elevation of the four cylinders, and Fig. 3 a section of the cylinder sleeve and pipes on the line Z—Z of Fig. 1. The four cylinders A are each fitted with sleeve valves B. Each cylinder cover or head C is formed with a water jacket. It is also provided with two ports H J oppositely disposed so that the two ports may be connected with two ports K L provided in the cylinder wall to correspond thereto. The two ports K L are on opposite sides of the cylinder in order that they may open directly into two separate pipes D M on each side of the engine respectively. Two other ports E N are provided in the cylinder wall which are respectively connected to

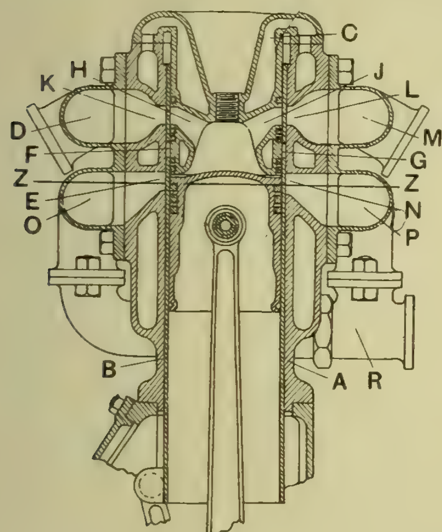


Fig. 1.

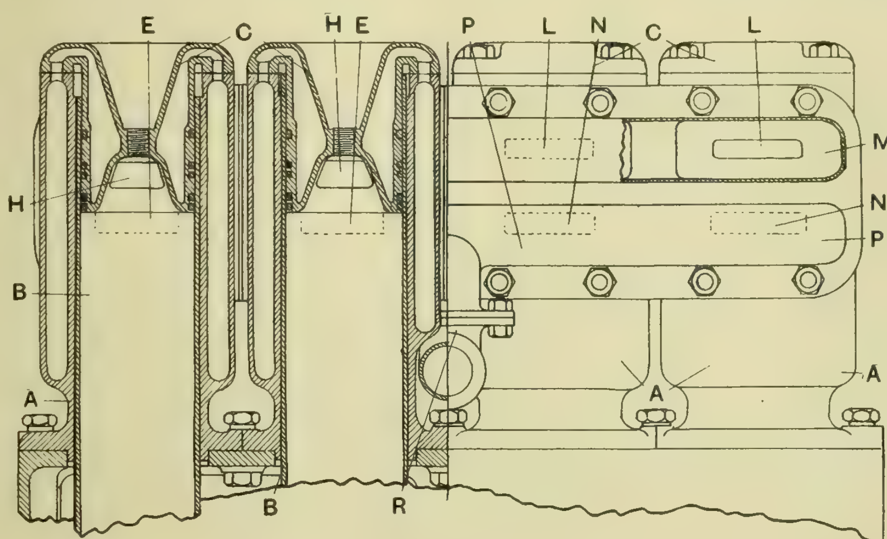


Fig. 2.

Roots' Internal-combustion Engine.

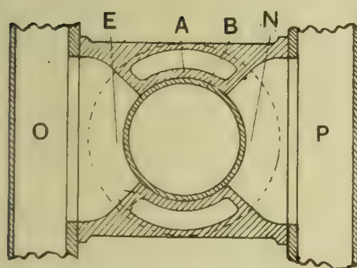


Fig. 3.

opposite pipes O P. The sleeve B is provided with two ports F G. These are shown in Fig. 1, in their mid-position, and between the cover and cylinder walls, in which positions they have packing rings immediately above and below them. At the upper end of the stroke of the sleeve B the port F registers with the port H in the cover or head and with the port K in the cylinder, the port G registers with the like opposite ports J L. At the lower or other end of the sleeve stroke the port F registers with the port E and the port G with the port N. The ports H J and K L and the pipes D M are for the exhaust or outlet of the gases. The exhaust pipes extend along each side of the 4-cylinder engine shown. Connection of the two pipes may be made at the end of the engine and one pipe then conveys the gases to the exhaust box or both pipes or channels may be continued separately to the exhaust box. The inlet ports E N of each cylinder are similarly connected by the separate pipes O P to one carburetter by the lower branch R which passes between the two middle cylinders of the four as shown. The sleeve B may be reciprocated in any convenient manner. In providing two outlet or exhaust ports, one on each side of the cylinder, and two inlet ports one on each side, both the double exhaust and inlet ports are so placed that in a multi-cylinder engine the respective exhausts and the respective inlets of each cylinder may be connected up in succession by pipes on each side of the engine. There is also no necessity to provide annular passages in the cylinder walls.

THE DEVELOPMENT OF ELECTRIC CIRCUIT BREAKERS.

BY E. B. MERRIAM.

THE demands of modern economic conditions have called for the concentrated production of electrical energy in large central stations. The control of this energy has presented many new problems in the design of protective devices, chief among which has been that of the automatic interrupter of abnormally loaded electrical circuits. For many years oil circuit-breakers and fuses were used with good effect on direct-current systems. When used on heavy-power alternating-current circuits connected to transmission systems, however, these devices set up line disturbances difficult to suppress. The large flaring arcs were also objectionable through their liability to involve adjacent apparatus, and on account of the great amount of room necessary for their proper isolation. Tests were made to find a suitable circuit-interrupting device for use on large-capacity systems. The various schemes tried included an air-break switch; a gravel switch; a switch in which an insulating shutter was thrown across the gap in order to shut out the arc; a lightning-arrester switch, in which the principle of the non-arcing multigap arrester was employed; a tube switch, in which a plunger in descending drew an arc into a tube with an opening at the top, the pressure developed in the tube blowing the arc out through this opening; a switch in which a blast of air was blown across the contacts, thus lengthening out and rupturing the arc; and switches having an upward or downward break in a suitable oil. Of these various devices, the most efficacious was found to be that in which the circuit was opened in oil.

The investigators, having found that an oil-break circuit interrupter was the most suitable, next turned their attention to finding out the most suitable type of oil circuit-breaker. With this end in view, they experimented with knife blades in oil, with drums similar to railway controllers, and with rods having a vertical or horizontal movement. This led to the development of a lever switch immersed in oil, which, for several years, remained the most efficient type of oil-break switch. As capacities increased, however, the limits of this switch were soon reached; and, as a result of the previous tests, there was developed a switch having a double downward break in oil. The stationary contacts of this switch were spring fingers, and the moving element was a bridging contact which connected the stationary ones when the switch was closed. This device had advantages in that the contacts cleaned themselves each time the switch

was operated; that there were a minimum number of points to be insulated from ground; and that the stationary contacts, when the switch was open, were always insulated from each other by a clean layer of oil, since as they were located near the top of the oil-vessel, most of the moisture and dirt in the oil gravitated to the bottom. The main advantage of this switch, however, was that it was possible to remove the oil-vessel for inspection of the contacts and renewal of oil without disturbing any other portion of the switch, particularly the connections. This switch as initially developed was in service on circuits up to 6,600 volts, and is still effective. The time soon came when transmission voltages began to pass this point, and rendered necessary the development of switches for use at higher voltages on larger systems.

A radical departure was early made in the design of the oil circuit-breaker. For controlling the larger-capacity circuits which were first encountered, investigations were made on a double upward-vertical-break switch, in which each break was made in a separate compartment. The first commercial device consisted of cylindrical oil-vessels, rather short for their diameter, in which the rods moved vertically upward, and in which the oil-chamber was practically sealed from the outside air. Owing to the air-tight nature of the oil-vessel, operating difficulties were experienced; and the next step was to open the oil chamber to air, placing suitable oil diverters in the top of the oil-vessel so as to deflect any oil which might be thrown out due to the opening of the switch and the formation of an arc. With increased generating capacities it was found that this switch at times ejected a quantity of oil, and it was next necessary to provide a suitable air space in the top of the oil-vessels to act as a buffer. Besides this, an increased vent space was found necessary, so that the air on top of the oil could be readily renewed, thus preventing the formation of explosive mixtures.

The maintained increase in generating capacities soon overtook the developments in oil circuit-breakers, and necessitated an additional investigation to increase the capacity of the device. As a result there was developed a baffle-plate for the vertical upward-break type of circuit-breaker. The function of this device was to keep the oil in the neighbourhood of the stationary contacts, for whenever an electrical circuit carrying considerable energy is opened in oil, gases are generated. These expand and rise, and tend to force the oil out of the containing vessel. They also form with air explosive mixtures, and either explode, or burn for a considerable length of time when ignited. It is seen, therefore, that oil circuit-breakers must be provided with strong oil-containing vessels in order that they may withstand the high initial stresses which are often present under certain conditions, and also that suitable provision be made for retaining the oil.

This type of switch remained standard for large-capacity systems for a number of years. The advent of the steam turbine-generator, with its greatly diminished internal reactance and correspondingly increased short-circuit current, increased the short-circuit current of systems beyond the capacity of this circuit-breaker. To meet the new condition further investigations were made, and suitable oil-diverting devices were introduced into the oil vessels. This practically doubled the capacity of the oil circuit-breaker, and, together with structural changes in the design of the oil-vessel, made the highly developed large-capacity oil circuit-breaker of to-day for use on moderate-voltage systems.

The present indications are that the oil circuit-breaker will not be developed very much further along the lines at present being followed; but that, for the control of very much greater capacities than at present found, some new lines of improvement will be necessary. At present it is proposed to take care of these greater capacities by subdividing the generating units into groups of less than 50,000 kw. It is not possible to apply it to all systems owing to the diversity of the loads which they carry, together with their method of distributing power. Another proposal is the introduction of current-limiting reactances, not only into the generator circuits, but also into the feeder circuits.

In the above outline, mention was made of the increase in the capacities of systems, reference being made principally to those of moderate voltage. At the same time the pressure of transmission lines has been gradually increased, until a point was some time ago reached beyond which the developed circuit-breakers were unsuited for the control of circuits of higher voltage. To meet the need for a circuit-breaker for use on high-voltage systems, a research was made for developing proper methods of insulating the terminals of oil circuit-breakers. Early investigations in connection with a 40,000-volt installation disclosed the fact that, for this pressure, wet-process porcelain made a suitable bushing; although it was found that simply increasing the dimensions of a porcelain bushing would not take care of the higher voltages soon to be encountered. The problem involved in designing a bushing is different from, and more difficult than, that of designing an insulator. It has been found that, owing to the electrical constants of these materials, no great benefit is derived from increasing the thickness of insulation, due principally to the uneven distribution of the electric potential. The result has been the development of two radically different types of bushings for insulating the leads of oil circuit-breakers. One of these is the so-called condenser lead, originating in Germany, and the other the filled lead, a product of the United States. These two bushings represent the results of a great deal of research in attempting to overcome the obstacles imposed by the very high voltages now used on long-distance transmission lines.

Other features of high-voltage circuit-breakers are their huge size and the great amount of oil necessitated by the requirements of insulation. It should be noted that oil circuit-breakers for use on circuits of moderate voltage have their overall dimensions usually fixed by the energy of the circuit which they control. Those for high voltage, however, have their size fixed principally by the insulation value of the mediums used in the construction of the device and the factor of safety required. At present it has been found advisable to use principally air and some insulating liquid such as petroleum oil for the insulation between ground and bare contacts of the circuit-breaker. It is thus seen that modern oil circuit-breakers are the result of extensive research, undertaken in order to meet the demand for apparatus which will efficiently and safely control the output of large electric stations.—"General Electric Review."

COAL DUST IN MINES.

A memorandum has been issued from the Home Office calling attention to the first report of the Explosions in Mines Committee, recently issued, with special reference to the use of inert dust in coal mines to prevent the ignition of coal dust. The Committee point out that their conclusions in respect of the action and use of inert dust in coal mines as a means of preventing or limiting colliery explosions are by no means final, and that it may be some time before the Committee are able from their own experiments to recommend compulsory precautions; but the Committee are of opinion that the principle that the use of inert dust in sufficient quantity protects against coal dust explosions is so far established as to justify them strongly urging its application on the owners of dusty mines. The steps that have been taken not only at Altofts, in Yorkshire, but also at the Charlaw, Sacriston, and Kimblesworth Collieries in Durham, at the New Moss Colliery, near Manchester, and elsewhere, to put this theory into actual practice, should be noticed. At the present time inert dust is not put on in zones, but is scattered by hand over the whole surface of such haulage roads as require it. This application of inert dust needs no considerable expenditure of capital, nor laying down of plant, and is not a costly operation, and the Committee are of opinion that even in the present incomplete state of our knowledge as to the exact action of inert dust, those who are working and carrying coal along dry and dusty roads would be well advised to take into consideration this means of obviating danger. The proposal to prevent the ignition of coal dust by admixture with an inert dust may not be applicable to all mines, but the results of the experiments, so far as they have gone, are sufficiently striking to merit serious attention. The Committee further report that stone dust, if made from shale or other argillaceous substances, has no injurious effect on the health of persons and animals employed in the mine. This is demonstrated by the experiments carried out by Dr. Beattie. On the other hand, dust containing finely powdered silica in its crystalline condition is apt to produce fibrosis of the lungs, and should not be employed.

INTERNATIONAL ENGINEERING AND MACHINERY EXHIBITION, OLYMPIA.—II.

Mr. Henry Milnes, of Ingleby Works, Bradford, a machine tool maker well known to our readers, has on Stand No. 17 an exceedingly interesting exhibit of his manufactures in the shape of lathes, planing machines, milling machines, and accessories. Four lathes are shown, viz.: A 6in. centre by 6ft. bed, high-speed, self-acting, sliding, surfacing, and screw-cutting machine, with hollow spindle of large diameter bore,

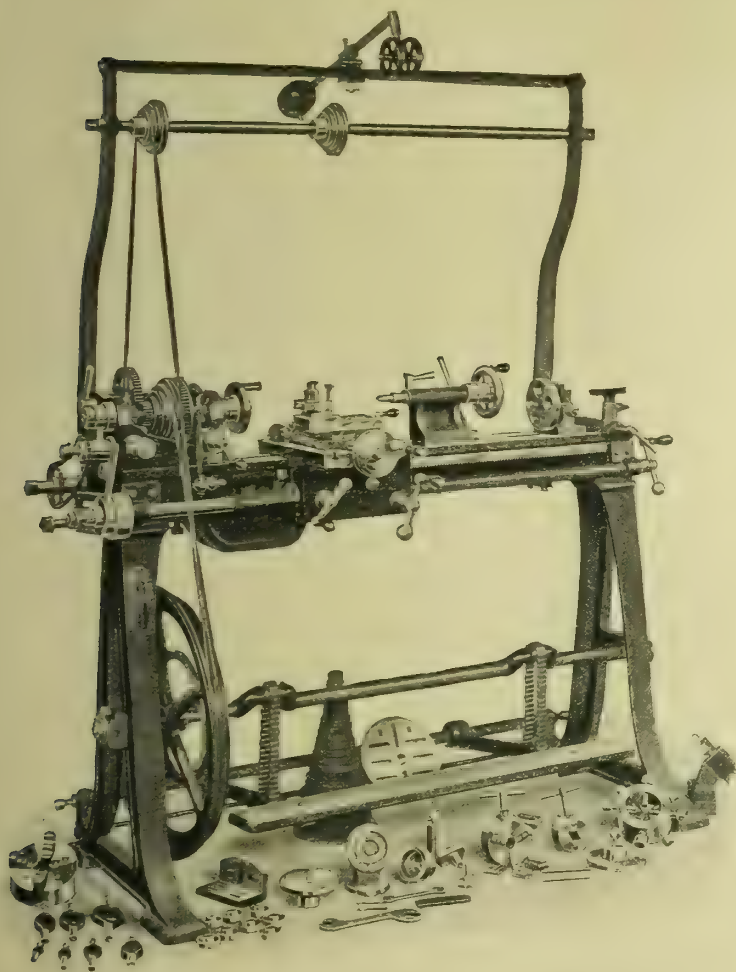


Fig. 1.—4½in. Centre Lathe with Overhead Gear, shown by Mr. Henry Milnes, Bradford.

and back traverse shaft; a 3½in. centre by 2ft. 6in. bed, self-acting, sliding, and screw-cutting lathe, with treadle motion and stand, boring table, hollow mandril, &c.; a 6in. centre by 6ft. bed, self-acting, sliding and screw-cutting lathe, of light build, with hollow mandril; and a 4½in. centre by 4ft. 6in. bed, self-acting, sliding, surfacing, and screw-cutting lathe, with overhead apparatus for ornamental turning, boring table, and dividing arrangement. This latter lathe we have pleasure in illustrating in Fig. 1, and the 3½in. centre lathe in Fig. 2, these illustrations being almost self-explanatory. The following points, however, are worthy of notice. In the case of the 4½in. lathe the hardened and ground hollow steel mandril of the double-geared headstock runs in parallel bearings of phosphor-bronze having concentric adjustment for wear, which, it is claimed, combines all the advantages of both conical and split bearings. A push pin in the front gear wheel allows of the cone being instantly locked or unlocked without using a wrench, and the wheels are put in or out of gear by a friction fastening eccentric shaft. The reversing motion has steel machine-cut cluster wheels and may be put out of gear or set for cutting right or left-hand screws, or feed, instantly, whilst the lathe is running, and without the use of a spanner. A division plate with four circles of holes, marked and figured so that it can be read at sight, is fitted, thus obviating the necessity of counting when used for the purpose of dividing, and there are also provided an adjustable micrometer spring stop, worm and segment wheel with tangent screw, and nine micrometer heads, plain drill chuck, fork chuck, flange chuck, cup chuck, face plate for wood, angle plate or chuck, bell chuck with eight screws, self-centring drill chuck, dog chuck with four independent jaws, geared scroll chuck, three jaw, with two sets of jaws, face plate, driver chuck, and a pair of cone centres. The tailstock is clamped to the bed quickly and firmly by an eccentric lever shaft; it being cut away on the front side to give clearance to the top rest crank handle in short work; the lead screw has 10 threads per inch so that a complete turn of the hand wheel advances the mandril $\frac{1}{10}$th of an inch, and a disc fitted on the hand wheel divided into 10 allows in drilling of the $\frac{1}{100}$th of an inch being measured. Automatic feeds for sliding, also surfacing, are given by a back traverse shaft driven by chain gear from the fast head reverse stud, as shown, or by change wheels at the will of the operator, but instead of back traverse shaft the lathe may be had, we understand, with splined leading screw driving a worm wheel put in action by a knurled knob on the front of the apron.

The 3½in. lathe takes 16in. between the centres, swings 5½in. over saddle, and has 2⅛in. between top of boring table and line of centres. It admits work 12in. diam. in the gap and the hollow mandril is ⅜in. diam. bore through. The double-geared headstock has parallel bearings and the back gear wheels are put in and out of gear by an eccentric shaft. The carriage, as will be seen, is fitted with compound slide rest, the lower slide of which is fitted as a boring table on which the swivel slide is placed. The latter it fitted to a graduated ring and may be set to any angle for taper work, also it can be taken off the boring table instantly, by just loosening one nut, when boring table is required for a boring job.

Several sizes of planing machines were shown, but the one illustrated in Fig. 3 may be taken as fairly representative of

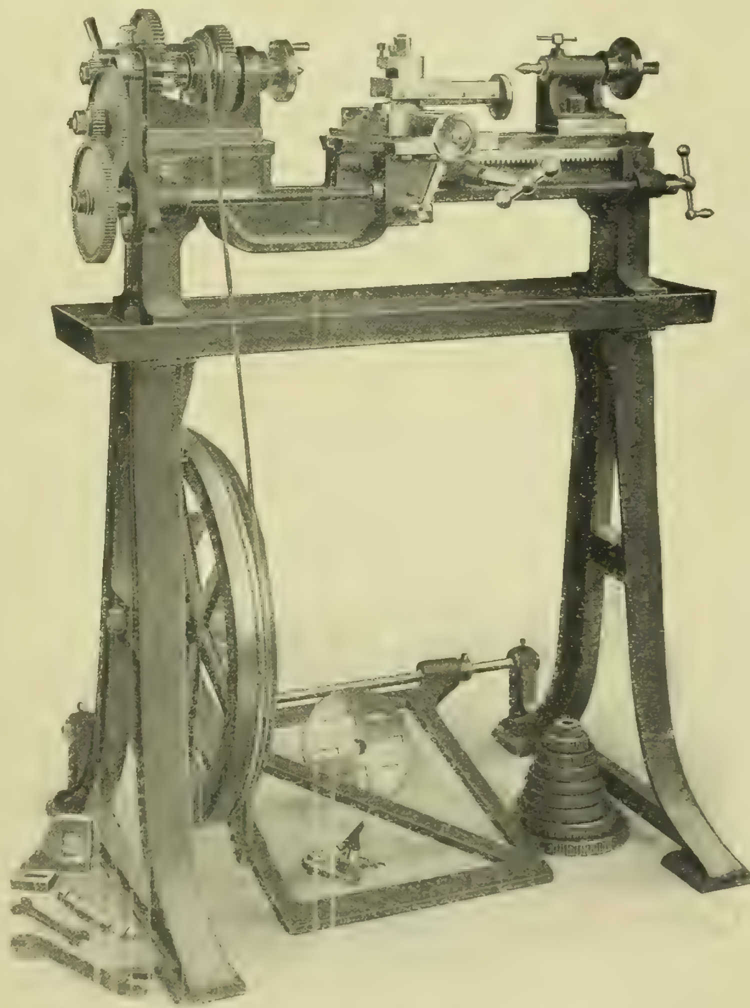


Fig. 2.—3½in. Lathe shown by Mr. Henry Milnes, Bradford.

the class of tool turned out by Mr. Milnes. They are all fitted up in a workmanlike manner, all sizes having self-acting feed in the horizontal cut, and the tables have true T slots cut by machine out of the solid. All slides are adjustable for wear, the main screws have square threads, and the teeth of the rack and all driving gear wheels are cut by machine out of solid. As illustrated, the machines are for hand power only, to plane 2ft. long, 12in. broad, and 10in. deep, but

power machines are made, the tables then being fitted with quick return motion.

Fig. 4 shows the milling machine for treadle or power to be seen on Mr. Milnes' stand. As will be noticed, there are four large and one small speeds on the driving wheel and thus

The milling heads have hollow mandril and are fitted with steel machine-cut worm wheel and tangent screw, division plate with spring stop, an arrangement for elevating one end for taper work, as well as supplementary swivelling table for angular work.



Fig. 3.—Planing Machine shown by Mr. Henry Milnes, Bradford.

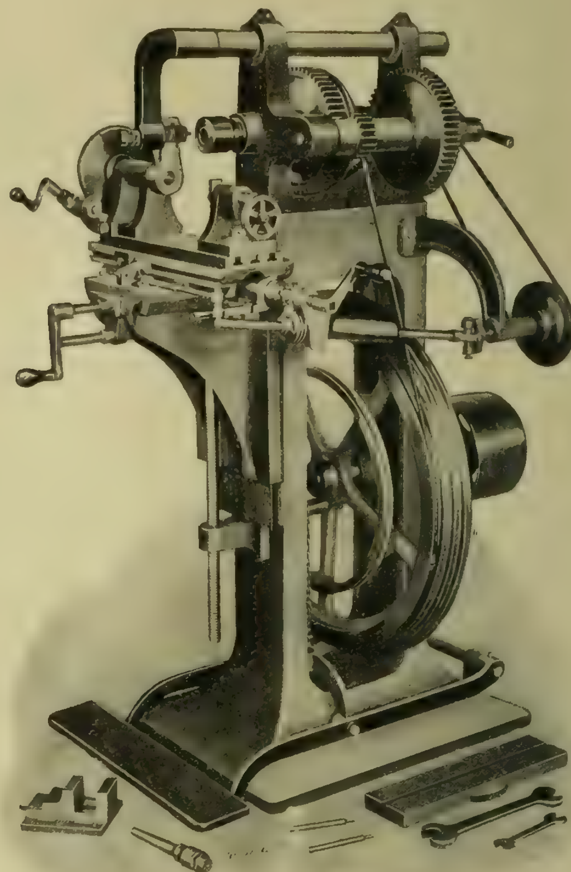


Fig. 4.—Milling Machine shown by Mr. Henry Milnes, Bradford.

with back gear 10 different speeds may be got. The hollow steel spindle has adjustable reversed cone bearings hardened and ground true running in hardened steel collars, and a ball race thrust. A draw-in spindle is fitted, and one arbor included for carrying circular cutters. The nose of the spindle is screwed to take chucks, and a cover is supplied to protect same when not in use. A push pin in front gear wheel allows cone to be instantly locked or unlocked without using a wrench.

The table is 15in. long by 7in. wide, and is provided with a well all round for collecting and conveying away the cutter lubricant. It traverses 12in. longitudinally, 6½in. transversely, and 13in. vertically, the longitudinal cut being self-acting. This can be thrown off definitely when travelling in either direction by a specially arranged means. The vertical and transverse slides are fitted with adjustable micrometers.



Fig. 5.—Inspector's Pyrometer Outfit. Foster Instrument Co., Letchworth.

Accessories are shown in great variety, but owing to the limited space at our disposal we can only find room to mention a few of these. They include all kinds of chucks, centres, drilling pads, angle plates, boring collars, mandrils, dogs, clamping plates, milling slides, geared wheel cutters, drilling spindles, tools, &c., in fact almost everything required for performing any operation in the lathe, planer, or milling machine.

Messrs. The Foster Instrument Company, of Letchworth, have an exhibit in the gallery of undoubted interest to engineers, in the shape of their well-known temperature indicating and recording instruments. The different pyrometers shown have been designed to withstand the inevitable rough usage met with in industrial practice. We are informed that the makers do not employ platinum wires, or tubes of porcelain, or quartz in the construction of their pyrometers, but that in place of these delicate and expensive materials others equally refractory but much cheaper are substituted.



Fig. 6.—Foster Recording Pyrometer. Foster Instrument Co., Letchworth.

The Foster fixed-focus radiation pyrometer is shown in several patterns. The simple portable outfit has been described in these pages previously. A recent development is the "Inspector's Outfit," shown in Fig. 5, in which a radiation receiving tube is combined with a thermo-couple stem, both read on one indicator. A collapsible tripod is added and the whole outfit is carried in a workmanlike leather

case. With an outfit of this type temperatures may be measured from 200° to 1,400° C. or 300° to 1,800° C., and a convenient method is thus available of controlling a wide range of heating processes.

Another variety of the fixed-focus instrument is made for work on small hot bodies, and may be fitted with an auxiliary refractory tube for immersion in molten metals. The cross ventilation device fitted to this latter type is interesting in its action in protecting the sensitive part of the instrument from damage due to fumes.

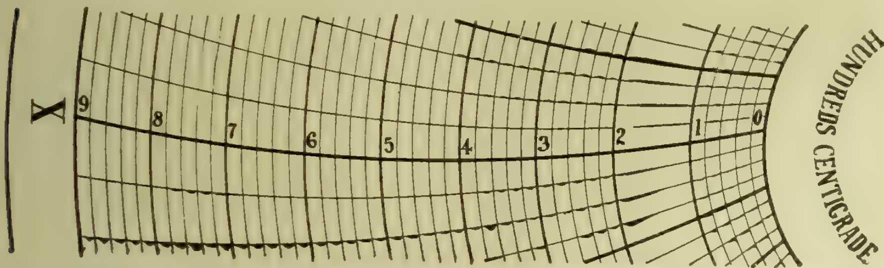


FIG. 7.—PART OF RECORDER CHART. FOSTER INSTRUMENT CO., LETCHWORTH.

The Foster Recorder is commendable for its simplicity and the absence of delicate parts. The moving coil controlling the pen is carried on double pivots. We are told that the charts are waterproof and do not fade nor smudge, and their marking is plain and easy to follow. Fig. 6 shows the recorder, while Fig. 7 is a reproduction of part of a chart. The same instrument, with suitable calibration, is used with the fixed-focus radiation pyrometer. A recent contract executed by this firm for the Indian Government Gun Factory includes eight of the latter combinations.

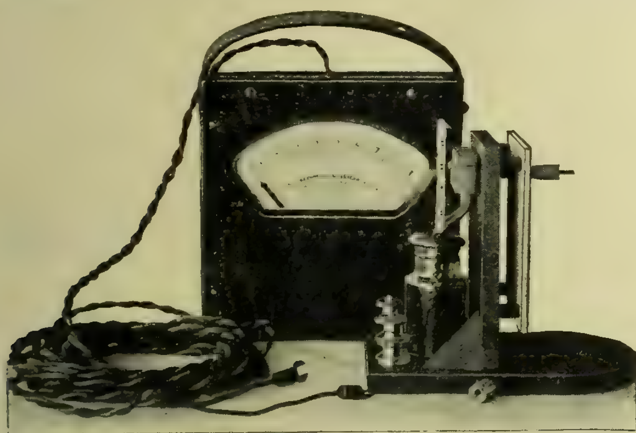


FIG. 8.—FOSTER RECALESCENT OUTFIT. FOSTER INSTRUMENT CO., LETCHWORTH.

The Recalescent Outfit is a simple piece of apparatus by means of which the critical or recalescent point of any sample of steel may be quickly determined. It comprises a small thermo-couple made of the Hoskins nickel-chromium alloys (for which the Foster Instrument Company are sole British licensees) connected to a portable indicator. Suitable arrangements are made for measuring and compensating for the "cold-junction" temperature. Upon the bare junction of the Hoskins thermo-couple a small sample of steel is mounted, and no danger from contamination need be feared with these thermo-couples. The steel sample is then heated by a bunsen flame to about 850° C. and then allowed to cool. The pointer of the indicator shows an unmistakable halt of some seconds' duration at the critical point. The outfit is illustrated in Fig. 8.

The Foster Strainmeter is also shown in operation. This little apparatus measures directly the strains in any loaded structure to which it is attached, and those interested will find a full description of same in "The Mechanical Engineer" of December 29th, 1911.

Messrs. The L. S. Starrett Company, of 36 and 37, Upper Thames Street, London, exhibit a very complete set of their well-known engineers' tools, and make a special display of micrometers. Amongst these will be found one which can be instantly opened or closed to any point within its capacity, and this without impairing its accuracy or sensitiveness in the slightest degree. As is well known, it requires 40 complete revolutions of the screw of the ordinary 1 in. micrometer to open or close it its full length, whereas in the one under notice it is done instantly, thus saving not only time, but the life of the tool, as it avoids the continual wear of turning the screw. To operate the micrometer it is only necessary to press the finger against the end of the plunger; this immediately releases the nut, disengaging it from the screw, when any adjustment within the 1in. may be instantly made. Releasing the pressure, the nut instantly engages the screw, when fine adjustment may be made in the usual way. This micrometer has the firm's patented sleeve and new lock nut, as supplied on the other micrometers, and is also supplied with a ratchet stop. It is made to read in thousandths, and is also made with a Vernier to read in ten-thousandths, as well as in the metric system to read to a hundredth of a millimetre.

A "hub" micrometer is also shown. This is especially useful in the manufacture of cutters and such articles where exact hub lengths are required. A specially narrow frame is used which will easily pass through a ¾in. hole, and thus it enables the user to take measurements that are impossible with the ordinary micrometer owing to the depth of the frame. This micrometer also is made to read in thousandths of an inch or hundredths of a millimetre.

Calipers, dividers, steel rules, steel tapes, squares, Vernier calipers, screw pitch gauges, protractors, thickness gauges, surface gauges, levels, drill and wire gauges, &c., are also to be seen in great variety, as well as Starrett hack-saw blades, both in the all-hard and in the flexible-back pattern, in sizes from 6in. to 24in.

Messrs. Joseph Hollis & Co., of 1, St. Paul's Road, Leicester, show a new type of wood trimmer or universal mitre machine for use in all woodworking trades, and we have pleasure in illustrating this in Fig. 9. This illustration shows how cornice moulds are held in position to cut the angle while the mould edge is resting on the flat table. By this means all work sets itself out at all angles correctly. This view also shows a Government stamped rule which is fitted to measure

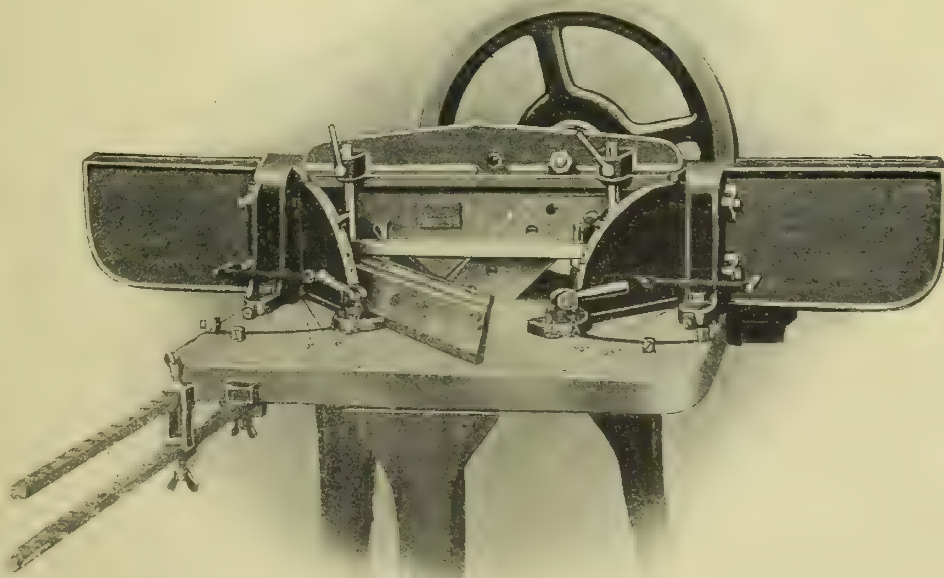


FIG. 9.—THE MASTERPIECE WOOD TRIMMER. MESSRS. JOSEPH HOLLIS & CO., LEICESTER.

off work from 1in. to 36in., or longer if desired. The machine cuts 21in. wide and 6in. high, and automatically measures by the rule all dead-length work. It also automatically fits all cornice moulds or fillets at one cut to exactly fit all angles or splays, has a canting table which

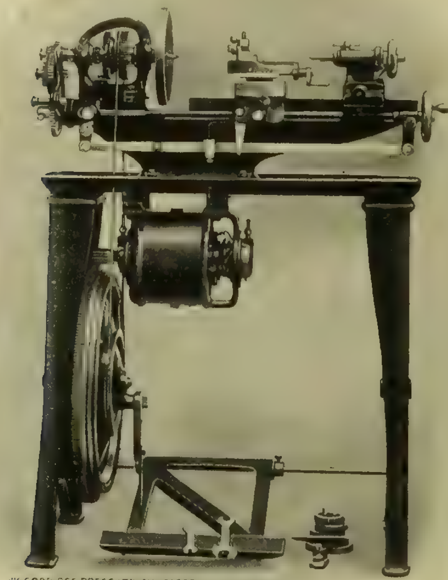


FIG. 10.—$3\frac{1}{2}$IN. LATHE. MESSRS. DRUMMOND BROS., LTD.

rests on the marked degrees on fences at 45°, 60°, and $67\frac{1}{2}$° to cut 21in., and is the only wood trimmer on the market that is designed to allow knives to be raised or lowered, so as to wear the knives all along.

Other features claimed are that it is the only machine on the market which is fitted with four fences, two external and two internal, so that both angles can be cut without moving either; and that no other trimmer is provided with three mitre positions, at $44\frac{1}{2}$°, 45°, and $45\frac{1}{2}$°, with stop pins so as to use either to make up for the difference when cutting hard woods and soft woods, or for doing work when the knives are dull, because at such times dull knives push off

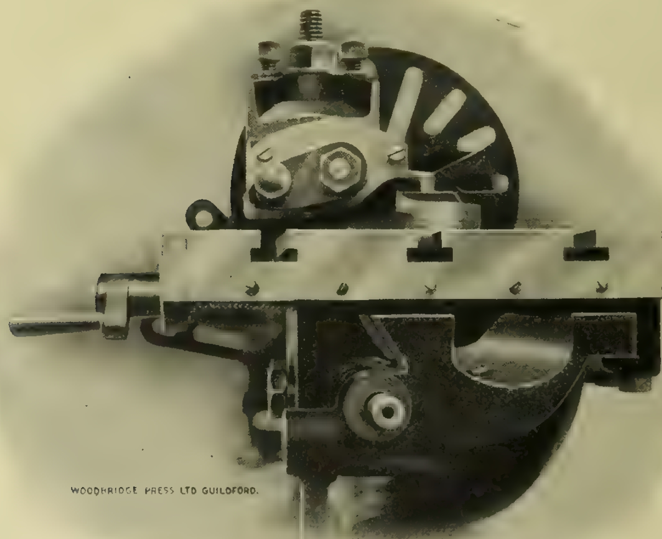


FIG. 11.—END VIEW OF BED OF $3\frac{1}{2}$IN. LATHE. MESSRS. DRUMMOND BROS., LTD.

the work more or less. Nor does any knife cut the same mitre with hard wood as with soft wood.

Another entirely new feature is the provision made for cutting belection moulds for panels, which are deeper than the rebate or moulds. This fitting adjusts the moulding to hold it up to match the panel, and also fills in the rebate width as well.

An ingeniously-designed fire escape was also shown by this firm to enable people trapped in burning buildings to get out very rapidly without any outside aid. This was shown in operation, and seems an effective device.

Messrs. Hunt & Mitton, of Cozells Street, North Birmingham, which firm have amalgamated with Smith's Injector Company (late of Nottingham) and Fletcher Bros. (late of Ashton-under-Lyne), have an exhibit of their well-known steam and water fittings, wheel valves, cocks, water gauges, pressure gauges, &c., which are too numerous to describe specifically. Boiler mountings, parallel slide valves, high steam and low water valves, lubricators, from the ordinary sight feed oil siphons to those of the force-feed type, are also shown in great variety, as well as fire-extinguishing appliances, such as landing valves, hydrants, branch pipes, and complete indoor and outdoor equipment. This firm is universally known as manufacturers of the above-mentioned goods, and their stand at the Exhibition is fully representative and makes a neat and effective display.

Messrs. Drummond Bros., Ltd., Ryde's Hill, near Guildford, Surrey, the well-known machine tool manufacturers, exhibit, amongst other tools, several new designs of lathe, three of which we have pleasure in describing and illustrating herewith. A "Drummond Barreto" turning, boring, drilling, milling, screw-cutting, and gear-cutting machine having self-contained electric drive is also shown, but as we have already fully described this machine (as adapted for belt drive), we

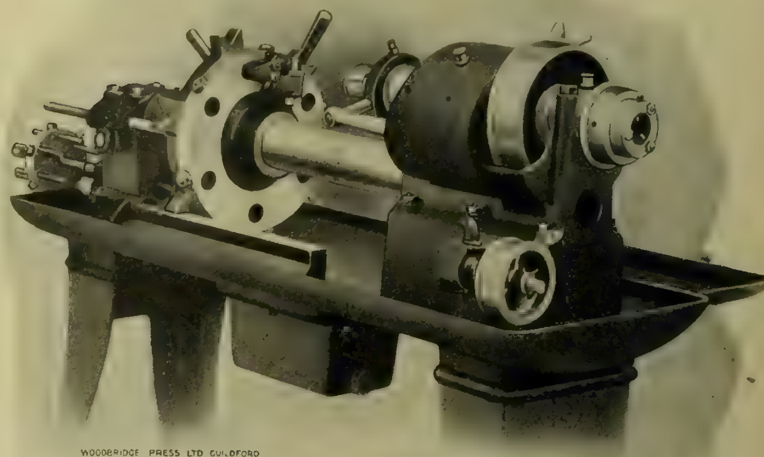


FIG. 12.—RING TURRET LATHE. MESSRS. DRUMMOND BROS., LTD.

will confine our remarks to mentioning that it may be used for turning any diameter from the smallest, say $\frac{1}{4}$in. up to 36in., being correctly speeded for this great range of work, ranging from 270 revs. per minute to 5 revs. per minute. As a lathe its centre height can be varied from 7in. to 18in., and it is as easy, quick, and convenient to handle as any ordinary screw-cutting lathe, although by removal of two nuts and slide rest it is instantly converted to a first-class boring and drilling machine with all conveniences usual on such tools. The placing in of the necessary upper bar and centre converts the tool to a milling machine of practically the usual form, whilst a powerful dividing head and supporting centre renders it, as a milling machine, "universal," capable of cutting spur, bevel, mitre, and worm gears from the smallest size up to 40in. diam.

Fig. 10 shows the entirely new design of $3\frac{1}{2}$in., back geared, self-acting, sliding, boring, and screw-cutting lathe exhibited by the firm. As will be seen, the bed is now a complete box section casting, a form not subjected to any distorting or squeezing strains. The saddle ways also are double, the linear guidance of the saddle being entirely taken on the front way formed with a flat vertical guide, a flat surface, and a vee front giving a long narrow guide and thus greatly increasing the accuracy of sliding when working. Fig. 11, which is a photograph taken from the end of the bed, will make this construction clear. It will be noticed also that the square and V front shear, which makes the long narrow guide mentioned above, is immediately over the lead screw which is

practically central with it. The square second shear at the back of the lathe bed takes tipping strains only, the saddle bearing on the top and bottom only to which it is gibbed, remaining always clear of the edge, however. The bed is of a form, as will be noticed, that is completely self-contained and stiff in itself and therefore needs no outside support from the tray or legs which is needful in most other designs, but which have the certain effect of rendering the bed inaccurate owing to such supports twisting the bed to conform to the inaccuracies of the floor on which the lathe is placed. Such a self-contained bed is the only form by which a small lathe can be made or guaranteed to remain accurate wherever placed.

The fast headstock has also been considerably improved by the addition of an overhead arm cast solid with the head; this keeps the bearings rigidly in line and with little additional weight stiffens the headstock against all strains. The tailstock has likewise been completely re-designed, its guidance now being similar to that of the saddle. The action of the single lever provided at the back rigidly locks it both to the front guiding way and to the square way of the bed at the same time that it locks it to the flat surface of the bed. Perhaps the most noticeable alteration is the placing of the lead screw outside the bed, but this, it is claimed, is as central with the saddle guide as it was in the former design, owing to the front saddle way *only* guiding the saddle.

A new ring turret lathe shown by Messrs. Drummond Bros., Ltd., is illustrated in Fig. 12. This tool was originally designed for use in their own works, and was an endeavour to overcome some of the troubles experienced in the use of turret lathes as ordinarily designed. A constant source of trouble in turrets, the giving out of the turret locating stop, usually a comparatively small affair located at a small distance from

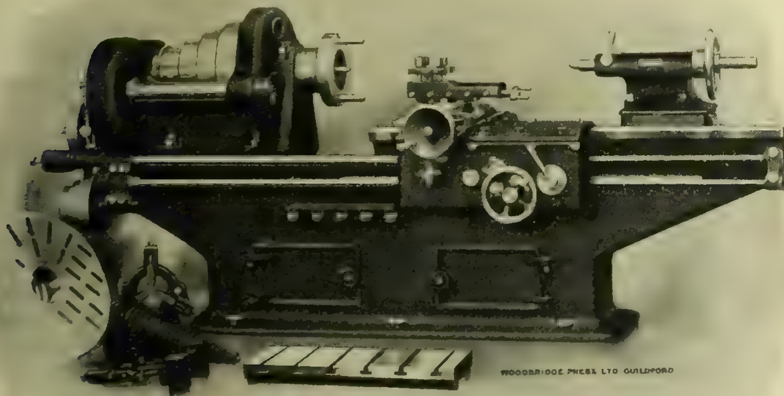


FIG. 13.—"COLONIAL" TYPE, 9IN. CENTRE LATHE. MESSRS. DRUMMOND BROS., LTD.

the centre of rotation, is entirely done away with. The location on this machine is, as will be seen, on the outside of the turret at a greater diameter than the centre line of the tool holes, and it is formed with a large surface bearing on a square guide solid with the bed. The machine is formed with a truly ground circular section bar bed, round which the turret revolves. This design gives so great rigidity that no locking down of the turret is necessary for the heaviest work and incidentally it gives a very large turret with correspondingly greater room for tools. The head is run by a constant speed belt and gives an open belt turning speed, stop, and geared down threading speed by the movement of a single lever which can be operated while the machine is running.

Another tool of interest on Messrs. Drummond's stand is the new design of "Colonial" type, 9in. centre, screw-cutting lathe, which we illustrate in Fig. 13. This, as its name implies, has been designed primarily for colonial shops, where a greater variety of work compared with the tools in use is taken on than is usual in works here, and often a comparatively small tool has to take a piece of work much beyond its rated capacity. For example, the lathe under notice, although rated as a 9in. centre or 18in. swing, will tackle work when required that would normally be given to a lathe of about double its rating, say, 15in. centre or 30in. swing. Very long jobs also frequently come in and have to be done somehow, although to have a lathe long enough for any chance job would be impracticable. A very usual such job is a repair to an artesian well tube, and to allow of work of this kind being done an abnormally large hole is arranged through the spindle. As will be seen, a gap bed is provided, and the cross slide is long enough to face at one setting any work that can be got into this gap. The general design of the tool will be seen by a reference to the illustration, but we may mention that the "back" gear is in this tool in front of the machine, so that when slow speeds with the corresponding increase in power are required, the point of application of the pressure is directly downwards in line with the cutting tool. The gap has a wide guide piece at the level of the bottom of the gap space on to which a guide formed on the saddle slides on bringing it over the gap. This gives a firm support and eliminates overhang, rendering the usual troublesome and inaccurate loose gap piece unnecessary. The tailstock main casting is an enclosed box section of parabolic design, thus disposing the metal along the lines of strain and giving the maximum rigidity possible in the space occupied by it. The barrel has the same full length bearing in the casting when fully extended as it has when drawn in, and a 1in. hole is bored clear through it.

DIESEL ENGINES FOR MARINE PURPOSES.

SOME interesting remarks were made on the subject of "Diesel Engines for Marine Purposes" by Mr. Charles Day in his presidential address recently delivered before the Manchester Association of Engineers. The development of the Diesel engine had, he said, been great and would undoubtedly continue, for there were many duties and many districts for which these engines had distinct advantages over any others. In his opinion, however, this development would not be injurious to other forms of internal-combustion engines, but would much more probably prove to be very advantageous. The Diesel engine was taking a strong hold on the marine trade, whilst the gas engine had been quite unable to secure a footing in that trade. The success of the Diesel in this direction would, he thought, prove of the greatest benefit to the gas-engine makers, and would open out a very large field for them to take part in. The Diesel engine would not be possible to-day had it not been preceded by the gas engine and other oil engines, and, in turn the experience which would result from the use of marine Diesel engines would help to bring gas engines into marine propulsion. At present there were fewer difficulties to be overcome in applying Diesel engines to marine propulsion than was the case with gas engines: hence it was natural that marine propulsion by internal-combustion engines should be first developed with Diesel engines.

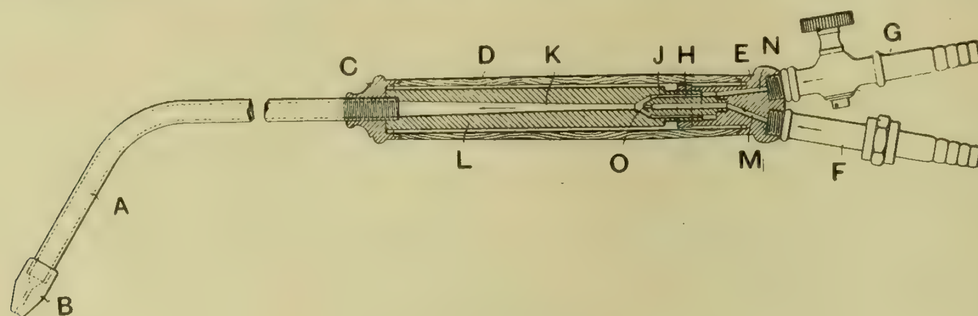
All internal-combustion engines suffered in one respect as compared with steam, viz., manœuvring power. The energy which drives them resulted from direct combustion in the cylinders of the engines, whilst with steam the energy from the combustion of the coal could be rendered available quite independently of the movement of the engine pistons. With internal-combustion engines there was no serious difficulty in arranging reversing mechanism, but as reversing had to be done by compressed air, a large air storage, or a separate compressing engine, was necessary if the main engine was connected direct to the propeller shaft. Long periods of running at very slow speeds must also be faced, and these speeds might be below the lowest speeds at which the engine could be run on oil or gas; hence the air storage or the independent compressing plant must be large enough to supply compressed air for this long period of running at slow speed. The alternative was not to connect the main engine direct to the propeller shaft, but to drive the propeller shaft through some form of clutch, or electrically. Mechanical clutches and reversing gears presented considerable difficulty in large

powers, though quite satisfactory in small powers. The Fottinger hydraulic transmitter might, he observed, prove to be a suitable clutch and reversing gear even up to large powers, as may also electrical transmission. Both of these methods were now being tried on a commercial scale.

A year or two's experience of the working of the various methods could alone decide which scheme was best, but in his opinion the soundest proposition at the present moment, even with the Diesel engine, was to drive the propeller by intermediate mechanism instead of by a direct connected reversing engine, and it was well to remember that with internal-combustion engines difficulties were most likely to occur at starting up and when running much below their normal speed. Also that the continuous-running engine had years of experience behind it. Arrangements, therefore, which eliminated frequent stopping and starting were of substantial advantage in connection with all internal-combustion engines.

OXY-ACETYLENE BLOWPIPE APPARATUS.

The accompanying sectional view shows the construction of an oxy-acetylene blowpipe designed and patented by The Thorn & Hoddle Acetylene Company, Ltd., 151, Victoria Street, Westminster, London. Referring to the illustration, A is the blowpipe, having the usual nozzle B at one end and at the other end being fitted with the plug or cap C attached to one end of the hollow cylindrical handle D, which is preferably made of wood, as shown. E is the plug, which is fitted to the other end of the handle, and F and G are external supply pipes, which are secured to the outer end of the plug E, and supply, respectively, the oxygen and acetylene. The tube F leads into the passage M, and the tube G into the passage N, both of which passages extend through the plug E. H is the hollow injector device which is screwed into a recess in the inner end of the plug E, and into which the passage M leads, the device being provided with the outlet orifice O and extending at its outer end into a recess in the inner end of the fitting L which is screwed into the recess in the plug E, and thence passes completely through the handle D. J is the annular space which surrounds the injector device and into which the passage N extends. K is the passage which is formed in the fitting L, this passage being, as shown, of a diameter which gradually increases from the injector end to that which is in communication with the blowpipe A.



Oxy-Acetylene Blowpipe.

With this construction of burner it will be understood that oxygen is supplied under pressure to the pipe F, whence it passes through the passage M into the injector device H through the orifice O, of which it issues, thereby drawing acetylene gas through the pipe G and passage N into the annular space J, the two gases, oxygen and acetylene, mixing, and thence flowing in the direction of the arrow into the passage K and finally into the blowpipe A from the nozzle B of which it issues.

Proposed New Laboratory at the Manchester School of Technology.—In the course of his presidential address, delivered on Saturday last before the Manchester Association of Engineers, Mr. Chas. Day pointed out that an effort is being made at the Manchester School of Technology to establish a really well equipped laboratory for dealing fully with problems connected with the internal-combustion engine, also for carrying out experiments in connection with aerial flight.

FURNACE ELECTRODES PRACTICALLY CONSIDERED.

At a recent meeting of the American Electrochemical Society Mr. R. Turnbull read a paper on "Furnace Electrodes," the subject being dealt with from the practical side. There are, he said, two classes of electrodes, the amorphous carbon and the graphite. It is the former to which I wish to draw attention, as graphite is prohibitive for ordinary furnace practice, owing to its high cost. The mixture used in the manufacture of the ordinary electrode is anything but a complicated one, being simply some kind of carbon mixed with certain percentages of pitch and tar. This, after being well mixed together, is moulded in some special apparatus to the desired form, and then baked in a furnace in a non-oxidising atmosphere. This looks simple, and when one looks back on the troubles and tribulations experienced by technical men in electric furnace work over quite a number of years due mainly to bad electrodes, it seems strange that the secret of making electrodes which would not break was not discovered long ago. But good electrodes were made from the very beginning, and it is quite possible that amongst the first batch of electrodes made some were equal in quality to the best electrodes made at the present day. This was where the great difficulty confronting the manufacturer lay, in his ability, unintentionally, to turn out a first-class electrode and a thoroughly bad one at the same time and under exactly the same conditions. Electrodes made at the same time, under the same conditions, and baked in the same furnace, have shown in actual service as many different characteristics in quality as could well be imagined, some giving excellent service whilst others simply went to pieces after being in operation for a few minutes.

In the early stages of electrode manufacture petroleum coke was mostly employed, it being first of all calcined to drive off all volatile matter. This was afterwards replaced by retort carbon, a kind of coke which is deposited in the retorts in gas works, and which is nearly pure carbon. Better results were obtained by the use of retort carbon than with petroleum coke, and it was considered for a time the only material with which a reasonably good electrode could be turned out. I have not sufficient data to enable to say when and where the first large electrodes were made, but I should not be far wrong in saying that they were first made by Dr. P. Héroult at his works in Froges, France, some 15 years ago; at that time he made them as large as 16in. square and 6ft. long. Some of these first electrodes manufactured by him were very good, and some very bad, and little, if any, reliable data could be collected from his work. I should like to say here, however, that Dr. Héroult has not abandoned the field, he having established works in Niagara Falls, N.Y., where excellent electrodes are now being turned out, and although the process used is different in some respects from his original one, he is still working along the same lines. His original process is still being used with good results at Welland, Ontario, by Electro Metals, Ltd.

Now, what was the reason of so many failures to turn out a good article in the early days, and why do nearly all electrode manufacturers, even those who have been but a short time in the business, turn out to-day a fairly satisfactory article? I think I am not far wrong in saying that the main cause of failure was in the use of the wrong carbon material. Petroleum coke did not work well, and electrodes made from it crumbled to pieces in the furnaces. Retort carbon made a better electrode, but as this commodity was collected from gas works all over the world, a homogeneous article could not be counted upon, and this made its use dangerous to the manufacturer, so far as reliability was concerned. It was only when anthracite coal came into use that real progress was made, and the best kind of electrodes in use to-day are made from this material. Hardmuth, of Venisseux, France, was, if I am not mistaken, the first to use anthracite coal on a large scale, and for some time his electrodes were the best on the market. He was quickly followed by the German makers, the Plania Werke and Siemens. We are indebted to-day to

the Plania Werke for the moulded screw, which enables electrodes to be joined together, thus doing away with the stub and machining of the electrode and the trouble of changing electrodes in the furnace. This screwed electrode applies mainly to furnaces for the manufacture and refining of steel.

At the present time nearly all manufacturers are using anthracite coal as the carbon base, and while electrodes made by some manufacturers are superior to those made by others, this is mainly due to the different methods of moulding the electrodes and preparing the coal employed. So much progress has been made in this industry in the last two or three years that perfectly satisfactory electrodes up to 24in. diam. and 7ft. long are now being made, whilst only a few years ago nothing over 12in. square and 5ft. long was satisfactory. No doubt still larger electrodes can and will be built, as electric furnaces are still growing in size, and the time is not far distant when steel furnaces of 30 tons capacity, and operating with electrodes 3ft. diam., will be as common as are our small 5-ton furnaces of to-day.

Before closing this paper, I would like to give a few hints as to the best manner of employing an electrode in order to ensure the best service and avoid the losses of which we have heard so much. Carbon, unlike metals, is a better conductor hot than cold, and the hotter it is, the better conductor it becomes. Carbon, however, even at a very high heat, is still a poor conductor, and it is impossible in actual practice to avoid some loss in the electrode itself. In all conductors, the longer the conductor, the greater the loss, but this loss can be lessened by increasing the size of the conductor. This same rule applies to electrodes, and in order to avoid all losses to the greatest extent possible the current should enter the electrode at a point as near as possible to the point where it will leave it. It is quite common practice to connect the metallic conductor to the head of the electrode, but this is a grave mistake, as the loss in volts in a long electrode will be from four to six, depending on the current density employed, and in a furnace where the operating voltage is 50 volts, this loss would be equal to from 8 to 12 per cent. of the total energy consumed.

Electrodes should be held in the same manner as one would hold a bar vertically in the hand, so that they can be taken at any point on their length, and in smelting furnaces the holder giving contact to the electrode should not be at any time more than 1ft. above the charge. As the electrode wears away it is slipped through the holder, and the process goes on until it is finally taken by the head, but at no time should the part of the electrode carrying the current project more than 2ft. 6in. from the holder itself. The losses, both of heat and energy, can be decreased by increasing the size of the electrode, but this can be carried too far. The writer would recommend a current density of from 30 to 35 amperes to the square inch of section in order to keep the electrode as cool as possible, and thereby prevent side oxidation and heat losses. With too large an electrode, quite a large percentage of the total energy supplied to the furnace would be required to keep the electrode warm.

An important point, the value of which is sometimes overlooked when considering the size of electrodes, is that it is often advisable to use electrodes of greater cross-section than electrical necessity demands, but for a totally different reason. In some processes, for instance, the electrode when working is surrounded to a certain depth by charge mixture. At the surface of such charge mixture, and, therefore, at some distance from the working end of the electrode, inflammable gases are given off, and these burning in air tend to attack and consume the electrode. Thus there is a tendency to reduced cross-section at this point with consequent increased current density, followed by rise of temperature, which further aggravates the condition described. It is, therefore, wise, for convenience sake, to use a larger cross-section so that the burning away does not result in eating the electrode through, letting a large piece of electrode into the charge and disturbing conditions generally. This is one of the exigencies imposed by practice.

Gas Engine Breakdown.—On the 10th inst. the crank shaft of a large gas engine at Messrs. W. Robinson & Sons' cardboard box factory, Chesterfield, broke, and the engine was practically wrecked. The engine tenter, who was standing near, had a narrow escape.

TYPICAL USES OF CAST IRON.*

BY JOHN J. PORTER.

It is now becoming quite widely recognised that chemical composition is not the only factor determining the properties of cast iron, but, although the importance of structure is known, the methods of metallography have received very little attention from foundries and users of castings. It is true that investigators have used the microscope on cast iron with valuable results, but this method of control has not yet been generally taken up in practice as in the case of steel. The two reasons which apparently account for this neglect are—first, the fact that foundries, being operated in smaller units, have as a rule less technical skill available at each individual plant; and, second, that the more complex structure of cast iron makes the interpretation of its microstructure much more difficult.

The theory that oxygen and nitrogen may be present in cast iron and are accountable for some otherwise unexplainable phenomena is gaining ground among practical foundrymen, and means of eliminating these elements are being widely adopted. Greater care is being given the cupola process, and the use of ferro-manganese, silicon, vanadium, and titanium as deoxidisers is rapidly increasing. Ferro-alloys are also rather extensively used to correct the composition of the iron in the ladle.

Since cast iron is used for a wide variety of purposes, it is obvious that the properties by which its value is measured and the tests to which it is subjected should be different for each class of castings. Hence it is necessary to consider each class separately. It is true that current practice does not as a rule adequately recognise this fact, and almost the only test which is commonly applied is that for transverse or tensile strength, although this property in many or perhaps the majority of cases is not of chief importance.

A large percentage of machine parts are made of cast iron, which material is especially adapted for this use on account of the ease with which it is cast and machined into the desired shape. The more important properties desired in machinery castings are softness, strength, and a fine grain structure, in addition, of course, to freedom from visible defects, such as blowholes, cracks, shrinkage cavities, &c.

It is an easy matter to make soft castings, but to get the combination of easy machining properties, strength, and close grain, as demanded by some users, has proved a difficult proposition to many foundries. Especially is this true as to closeness of grain and the ability to take a high polish, which is so desirable on many finished parts. The solution has been reached in various ways. The use of charcoal iron is one method, satisfactory except from the standpoint of cost. Certain brands of coke irons are found to give greater strength and closer grain for a given softness than others, and the knowledge of such mixtures is a valuable asset to the practical founder. Another method is found in the use of steel scrap in the cupola mixture, making the so-called semi-steel, which gives a closer grain structure and considerably more strength without material change in composition. The treatment of the metal with certain ferro-alloys has also been found advantageous in this connection.

The buying of machinery castings would be greatly simplified if definite limits of hardness, strength, and grain size could be specified. Satisfactory methods for testing hardness are found in the drill test and the Shore scleroscope, most of the various other proposed methods being too cumbersome for commercial use. The drill test, simulating as it does actual machining operations, gives the more reliable results, while the scleroscope possesses the advantage that it can be used directly on the casting without in any way injuring it.

For testing the strength of cast iron there are available the ordinary transverse, tensile, and compressive tests, the first of which is, in the opinion of the writer, preferable. In the testing of strength (and hardness also) it must be remembered that the properties of cast iron depend in part upon the thickness of the section, and hence that, in cases where it is not possible to test the casting itself, the test piece should at least

* Paper presented at the International Congress for Testing Materials.

approximate the section of the casting. Probably three standard sizes of test bars could be selected, to represent the three classes of light, medium, and heavy castings. The broken ends of these bars could be then used for the drill test to determine hardness.

For grain size there is no practical test available—a serious lack, as in many cases this property is of the greatest importance. Possibly something might be done with a planimeter used on a microphotograph of standard magnification. A rough test, of value in some cases, can be made by comparing the fracture of a broken test bar with a scale made of previously broken test bars of varying grain size.

The freedom from blowholes and other casting defects is best determined by ocular inspection. Unfortunately, there is no method of inspecting the interior of the casting without destroying it, and while the tendency of the iron to shrinkage, blowholes, &c., can easily be tested, such tests would be of doubtful utility, since these troubles are frequently, if not usually, due to faulty moulding and pouring.

Cast iron is still very generally used for hydraulic work, on account of the ease with which it is formed into shape, although there has been some attempt to substitute steel for very high pressure. The properties desired in the metal are practically the same as in the preceding case, except that they stand in a different order of importance, close grain and freedom from shrink-holes and spongy places being the first consideration. Much the same means are used to obtain the combination of density, strength, and the ability to machine easily, but, as the importance of density is greater in this case, the use of special means, such as charcoal irons, steel scrap, and ferro-alloys, is more frequent.

The most direct and satisfactory test for hydraulic work is to subject the casting itself to some specified hydraulic pressure. In many cases, however, the casting cannot be so tested until a good deal of expensive machine work has been done on it, and in this event it seems advisable to specify the strength and hardness tests previously described. The hardness test should be used in any case, as the bursting strength does not, of course, give any idea as to machining properties. A test for grain structure would be especially valuable in connection with this class of work.

For parts where high electrical permeability is of prime importance, cast iron has been largely displaced by steel, but in the majority of cases it still holds its own on account of the greater ease of forming. The permeability of cast iron, although always low as compared with that of the purer forms of iron, can be considerably improved by keeping the manganese very low and the silicon quite high. In practice, however, not much attention is usually given to this property, since the greater number of castings are used in parts of machines not carrying the magnetic lines of force, and hence having requirements not different from ordinary machinery castings.

In electrical castings a permeability test used in conjunction with strength and hardness tests should be sufficient to define the quality of the material. Since permeability probably bears a fairly close relation to chemical composition it might be possible, although certainly less satisfactory, to specify analysis in place of permeability direct.

A large variety of castings must be classified as heat and chemical-resistant; the best known examples are probably ingot moulds and grate bars. Only a few foundries are giving attention to producing castings of these special properties, and there is but little generally available information. Grate bars, for example, are ordinarily made of the cheapest possible mixture irrespective of its quality as regards service. In the case of ingot moulds, on the other hand, some pains are taken to obtain the special quality of heat-resistance, and a low-phosphorus iron is always used for this purpose.

There are no tests for heat-resistance and chemical-resistance of cast iron in common use. For heat-resistance it is a very difficult matter to devise any single test which will answer for all classes of castings, since the effects of heat are manifested in several different ways. Chemical analysis may be specified with advantage in some cases, since the melting point of cast iron depends chiefly on this factor. Resistance to the action of chemicals can be tested directly without much difficulty in a manner similar to the accelerated corrosion test used on steel. There is, however, great need for the standardisation of all conditions under which such tests are made, so that comparable results may be obtained.

Chilled car wheels form one of the most interesting applications of cast iron. The service conditions for these wheels are very severe. The load on each wheel often amounts to between 10,000lbs. and 20,000lbs. They are constantly subjected to heavy blows due to pounding at rail joints. The friction of the brake-shoes induces severe heat strains in the tread. Finally, the users of these wheels demand that they have a high resistance to wear. Owing to the nature of their service any failure is apt to be attended with very serious results, and hence great pains must be taken to ensure a uniformly high quality of product.

The results desired are produced by the use of both special materials and special methods of casting. Formerly, charcoal iron was used exclusively for this class of work, but now coke iron enters largely into the mixture. The problem of a high-grade mixture has been much complicated by the necessity of re-melting the old wheels, with their usual high content of sulphur. A partial corrective for the excessive amount of scrap which it is often necessary to use is found in the addition of ferro-manganese, and there have also been obtained some encouraging results through the use of ferro-titanium.

The special methods of casting consist in the use of a circular chill in that part of the mould forming the tread of the wheel. This method has been frequently described and needs no discussion. With the proper percentage of silicon this results in the tread being chilled to a depth of about ¾in., back of which is tough grey iron. The chilled tread is, of course, intensely hard and exceedingly resistant to wear, while the wheel as a whole is very tough, and has proved eminently satisfactory in service. Steel wheels, long used on passenger cars, have recently been substituted on freight cars of very high capacity. They are, however, much more expensive, and in some cases have not proved entirely satisfactory as to wear, so that there is every indication that the cast-iron car wheel will hold its own for a long time to come.

The specifications and tests required for car wheels have been so often published and are so readily accessible that they need not be repeated at length. Briefly summarised, the tests are carried out on a certain number of the castings themselves, and consist chiefly of a drop test to measure the resistance to shock and blows, a heat test made by pouring molten iron around the tread of the wheel, to measure the resistance to heat strains, and measurements to verify dimensions. It would appear that a hardness test on the chill might advantageously be added, in view of the known variation in the hardness of chilled iron. A test for wearing quality would be better still, but no satisfactory test of this sort is in sight.

Cast-iron rolls still hold their own in sheet mill and some other classes of finishing work, although cast iron has been quite generally displaced by steel for the heavier service. In this case the service conditions are not unlike those to which car wheels are subjected, but they are even more severe as to heat strains. Moreover, owing to the great thickness of the castings, the initial shrinkage strains are very great. The use of the very best grades of charcoal iron, together with air furnace melting, is generally recognised as necessary for the successful manufacture of chilled rolls, chiefly on account of the difficulty with cracking due to heat strains. It is reported that the use of vanadium in chilled rolls is adding considerably to their wearing qualities. For this class of castings there are no satisfactory tests in sight. It is inconceivable that any tests could be of value which are not made on the roll itself, and, while a difficult proposition, it is possible that in time a set of tests similar to those used on car wheels may be devised.

Brakeshoes may serve as an example of the many smaller specialities which are made of cast iron. The requirements here are long life, with this limitation: That the hardness of the brakeshoe must be less than that of the wheel, so that the wear will not be on the wheel. A close grain structure is advisable, and in some cases at least is being obtained by the use of steel scrap in the cupola mixture. For brakeshoes a wearing test used in connection with hardness limits would best define their quality. No satisfactory method of testing resistance to wear is in sight, but it would seem that specifica-

tions for hardness alone could be advantageously used pending the development of such a test.

Cast iron is a particularly suitable material for pipes which are to be placed underground, on account of its relative resistance to corrosion as compared with steel and other commercially available materials. Competition is keen in this line, so that low-priced iron is necessary. Within the limitations set by price, close grain and strength are desirable, while hardness must be kept within such limits as will permit of a small amount of machine work. In regard to the properties of the metal, none of the present specifications for cast-iron pipe lays stress on anything other than strength as determined on a separately cast test bar. A test for bursting strength and freedom from leakage made directly on the pipe would, of course, be a more accurate index of utility, but is probably too cumbersome for practical use. The transverse strength determination is probably as satisfactory as any simple test could be, but might with advantage be supplemented by specifying hardness limits.

Malleable cast iron and steel have been tried for stoves, but while they have perhaps a place, grey cast iron has proved more satisfactory and has steadfastly held its own. The service requirements here are resistance to the action of heat, resistance to warping, and a certain degree of strength. However, as these castings are very thin and are frequently highly ornamented, a very fluid iron is essential, and in practice the service requirements are deliberately ignored to facilitate manufacture. Resistance to heat requires low phosphorus, and resistance to permanent expansion, which causes warping, demands low silicon, but both phosphorus and silicon are invariably carried high in this class of work, to increase fluidity and make it easier to produce perfect castings. However, the product of our stove foundries is fairly satisfactory in service, and in appearance and finish has reached a high degree of perfection.

Specifications for stove and furnace castings should include tests for strength, hardness, since many parts have to be drilled, and resistance to heat. There is no trouble in regard to the first two tests, but, as previously stated, no good method has yet been devised for gauging heat-resistant qualities. Specification of chemical analysis can be used with advantage, but cannot be regarded as a really satisfactory substitute for the much-needed direct test for heat-resistance.

Locomotives for French State Railways.—There has recently been put into service on the French State Railways a number of new locomotives, intended to work the international express traffic. They are of the 4—6—0 type with a leading bogie and six coupled driving wheels 6ft. 8in. diam. All are fitted with superheaters and have four single expansion cylinders (two outside and two inside), the first coupled axle being driven by the inside cylinders and the second one by the outside cylinders. Their weight is 72 tons in running order, and they are coupled to bogie tenders.

British Foundrymen's Association: Scottish Branch. — The opening meeting of the Scottish Branch of the British Foundrymen's Association was held on Saturday last at Glasgow. Prof. A. Campion occupied the chair, and the recently elected president, Mr. William Mayer, delivered his presidential address. He made the subject of his address "The Rise and Progress of Ironfounding," and dealt with his personal experiences during a 50 years' connection with the trade. The foundry engineer, he said, had frequently been the pioneer in important spheres of activity so diverse as bridge-building, agricultural implements, and marine engineering, and he looked to the foundryman maintaining his place by utilising electricity for his smelting operations and adopting more perfect standardisation of parts in his moulding operations. Mr. A. Laurie, of Hurlford, read a short paper upon "Pressure: Its Cause and Effect," in which he dealt with the various problems connected with this phenomenon. He said air pressure in the mould was not so important as the more powerful ferro-static pressure due to the liquid metal, and after comparing this with hydrostatic pressure he discussed several cases in which precautions must be taken to guard against its ill-effects upon castings.

THE INFLUENCE OF IMPURITIES IN "TOUGH-PITCH" COPPER.*

WITH CHIEF REFERENCE TO ANTIMONY.

BY FREDERICK JOHNSON, M.SC., A.I.M.M.

IN continuation of a series of experiments carried out with a view to ascertaining and placing on record the varied influences of traces of impurities on the useful properties of copper, the author now presents the results of experiments which, in the main, have been directed toward the determination of the influence of antimony on "tough-pitch" copper. More than any other property, it is desirable that commercial copper should possess the property of malleability at a red heat. Copper which is "red-short" is the bête-noire of the manufacturer, and experiments which indicate the nature and extent of the influence of impurities on this property cannot fail to be of service to him. Assuming that copper containing impurities can be successfully rolled hot, it remains to show whether such copper will have mechanical properties inferior, equal, or superior to those of pure copper, and to show also, if possible, the structural condition of those impurities.

PREVIOUS INVESTIGATIONS.

Of previous investigations, that of Hampe demands first attention. He found that: (1) Copper with 0·529 per cent. antimony could be drawn into wire; (2) copper with 1 per cent. antimony was extremely "red-short"; (3) antimony in small amounts increased the tenacity of copper, but lowered its conductivity. Dealing with its presence in copper in the form of salts, Hampe discovered several notable facts in addition to the foregoing. As antimonate of copper, no "red-shortness" was experienced when there was sufficient present to correspond to 0·5 per cent. antimony, whereas with 0·5 per cent. antimony in the metallic form incipient "red-shortness" was produced.

A point which Hampe appears to have overlooked, however, is that when a compound such as the foregoing is added to a molten metal which dissolves it, it does not necessarily follow that that compound will retain its individuality in the solidified metal, although its effects may be less harmful than those of metallic antimony. As will be shown later, when antimonious oxide (Sb_2O_3) is added to molten copper, it is decomposed by the copper, and does not exist as the original, unaltered compound after the metal has solidified and cooled. Experimenting with antimonate of bismuth, Hampe stated that neither red-shortness nor cold-shortness occurred with less than 0·7 per cent. of this compound. That the protective influence of antimony and oxygen in the presence of so much bismuth can be so marked is open to grave doubt.

Hiorns† and Lamb place the limit of antimony as 0·6 per cent. for wire-drawing. With more than this amount, wires could not be successfully produced. They also found that antimony very seriously lowered the electrical conductivity (0·10 per cent. causing a lowering of 24 per cent.), increased the hardness, had a decolorising effect, and was less efficient than arsenic in producing soundness.

Hiorns,‡ as a result of experiments on the cold rolling of small ingots, concluded that: (1) Arsenic and antimony were better than antimony alone; (2) antimony (0·20 per cent.) when added to copper containing lead (0·2 per cent.) diminished the brittleness caused by the lead. With regard to the joint action of antimony and oxygen, he assumed that antimony would react with cuprous oxide to form the higher oxide, Sb_2O_5.

Greaves§ investigated the influence of oxygen on copper in the presence of antimony, and found that an increase of oxygen had no definite effect on the tensile strength of cast copper containing a constant percentage of antimony, but caused a serious reduction in ductility, as measured by percentage elongation. As will be shown later, this is not true for rolled annealed rods. Greaves also found that where the electrical conductivity had been lowered by antimony, the

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* Paper read before the Institute of Metals, September, 1912.

† "Journal of the Society of Chemical Industry," May 15th, 1909.

‡ Ibid., July, 1906.

§ "Journal of the Institute of Metals," No. 1, 1912, Vol. VII., p. 218.

addition of oxygen tended, to a slight extent, to neutralise that effect, causing a slight recovery of conductivity.

T. Johnson* gave the following results of tests on antimonial copper:—

	Tensile Strength. Tons per sq. in.	Elongation per cent. on 2 inches.
Copper with 0·25 per cent. antimony...	15·17	49
,, 0·50 ,, ,, ...	15·60	45

The oxygen contents were not given, but some oxygen was undoubtedly present. The ingots were rolled hot and cold, and the strip annealed before testing.

Lewis† concluded, from a series of rolling experiments on copper containing added quantities of impurities, that arsenic had the property of neutralising the injurious effect of antimony, 0·10 per cent. antimony having a worse effect on the hot-working properties than the same amount in the presence of 0·6 per cent. arsenic.

Archbutt‡ confirmed the harmlessness of antimony on the hot-working properties of copper.

It will be seen that, of all the foregoing investigators, one only (T. Johnson) produced ingots strictly comparable with those of commerce—that is to say, in the "tough-pitch" condition. The author observed the last-named condition by carrying out his experiments in a similar manner to that previously adopted.§ The purest electrolytic copper (procured from Messrs. Vivian & Sons, Swansea) and chemically pure antimony were used.

Influence of Antimony during the Poling Operation.—By noting the behaviour of small trial ingots, the author was able to record a number of interesting facts. (1) That with antimony present up to 0·3 per cent., the copper has splendid hot-working properties, either under or up to "pitch." (2) That with more than 0·3 per cent. antimony, the removal of oxygen by poling is synchronous with inferior hot-working properties. This observation is borne out by the behaviour of ingots A1 and AA1 (see Table I.). The poling in the case of A1 was pushed beyond the "tough-pitch" stage (in so far as the percentage of oxygen is concerned). This is explained by the following observation: (3) That, although the influence of antimony is to render the copper "red-short" (after the removal of oxygen), and thus "overpoled" according to one interpretation of the term, yet its effect is really to prevent "overpoling" as indicated by the "rising" or "spewing" of an ingot. The two latter terms are used to describe the physical phenomena exhibited by an ingot during solidification. The raising of the surface or the ejection of molten copper through the top crust of the ingot are due to the escape of gases which excessive poling has introduced into the copper.

Either the action of these gases is neutralised, or their entry into the molten copper opposed, by the antimony. The author prefers the latter explanation. It is, therefore, possible to cast an ingot (A1) which, owing to the presence of antimony, has a level surface, but which, were it free from antimony, would "rise" or "spew" after so much "poling." The removal of the oxygen has, however, from the rolling point of view, caused the ingot to be "red-short." On the other hand, the "underpoled" ingot (AA1) rolled splendidly, but this property has been gained at too great a cost, because the oxygen in excess seriously affects the toughness and cold-working properties of the copper, and also causes a depression to form on the surface of the ingot. This depression is closed up during the rolling, and remains in the rod as an unseen but dangerous flaw. All the ingots used in this research, with the exception of AA1, had level surfaces.

Referring again to the influence of antimony in checking the absorption of gases during poling, it may be pointed out that it is not without its value nor its danger in the refining of "tough" copper. There is nothing so trying in the refinery as a charge which has gone "over the pitch." "Spewing" ingots (cakes, billets, &c.), inferior malleability, lost time in bringing the charge back to "pitch," all contribute to give the refiner much anxiety. Any impurity in the copper which will check this tendency of the charge (under certain conditions) to go "over the pitch" is, therefore, welcome. Arsenic is such an impurity, and the author has just shown that antimony is another. A little antimony even in arsenical copper should also be beneficial. Lead has always been recognised as having a similar influence, but lead is wholly undesirable in wrought copper.

Having pointed out the value of a little antimony, it now remains to indicate the danger. This lies, of course, in having too much present, and so masking the true "pitch" of the copper, that it is "red-short" before the other signs of "overpoling" or going "over the pitch" have become apparent. There is yet another side to the question. Antimony hardens copper for rolling, and this becomes serious if it prolongs the "breaking-down" operations. For a normal, soft, tough arsenical copper, however, the author considers that 0·10 per cent. antimony would be a beneficial addition. The presence of other impurities would modify this proportion. Such copper could not be used for making malleable alloys, *e.g.*, brass. From high conductivity copper, also, antimony must be rigidly excluded.

Incidentally the author would like to dispose, once and for all time, of the fallacy that pure electrolytic copper is immune from "overpoling." The statement has been made by well-known metallurgists so often that it demands immediate refutation. Such copper has, possibly, a greater solvent power for gases than most less pure brands, and, in addition to meeting with overpoled electrolytic copper in the refinery, it has been the author's experience that "tough-pitch" ingots of electrolytic copper are the most difficult of all to produce on an experimental scale. Such copper, although never becoming "red-short," is just as liable to become porous or to "spew" after overpoling as any other kind, and more liable than many kinds.

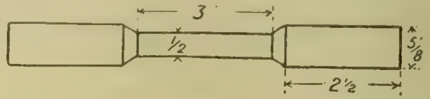


FIG. 1.

THE ROLLING OF INGOTS.

The ingots (1¼in. square) were rolled at a red heat about 900° C. (the usual temperature for rolling arsenical copper, as judged by an experienced hand) in the works of Messrs. Vivian & Sons, at Margam (Port Talbot). They were rolled hot in six passes to 11/16in. diam., finishing at a dull red heat, annealed by raising to a bright red heat, quenched in the pickling bosh (to remove scale), and then rolled cold to ⅝in. (full). Finally, they were drawn once through a die to straighten and to confer on them a smooth and truly round surface. These rods will subsequently be designated "as rolled." Their compositions are given in Table I.

TABLE I.

Mark on Rod.	Antimony per Cent.	Arsenic per Cent.	Oxygen per Cent.	Appearance of Ingot.	Behaviour during Rolling.
RR	Nil	Nil	0·050	Level surface.	Rolled perfectly.
A3	0·2	Nil	0·058	Do.	Do.
A2	0·29	Nil	0·054	Do.	Do.
AA2	0·3	Nil	0·063	Do.	Do.
A1	0·5	Nil	0·02	Do.	Red-short at 3rd pass
AA1*	0·49	Nil	0·33	Surface depression.	Rolled perfectly.
A	0·2	0·36	0·065	Level surface.	Do.

* Rod AA1 was prepared purposely with a considerable excess of oxygen.

All the ingots offered more resistance in their passage through the rolls even at a red heat than the pure copper ingot RR, which had a rougher surface, owing to its greater softness and its inability to resist the "scoring" action of the rolls. Ingot A1 was red-short, and was removed from the rolls at the third pass.

METHODS OF ANALYSIS.

Oxygen.—The method was similar to that described in a former paper by the author.* In order, however, that the fears of the ultra-exact might be allayed, the author prepared the strips for analysis by cold rolling. Thus there was no

* "Birmingham Metallurgical Society Proceedings," March 8th, 1906.

† "Engineering," December 4th, 1903.

‡ "Journal of the Institute of Metals," No. 1, 1912, Vol. VII., p. 263.

§ "Journal of the Institute of Metals," No. 2, 1910, Vol. IV., p. 174.

* "Journal of the Institute of Metals," No. 2, 1910, Vol. VI., p. 185.

Table II.—*Tensile Tests.*

Mark on Rod.	Rods as Rolled.		Rods Annealed.		Composition.			
	Tensile Strength. Tons per Sq. In.	Elongation per Cent. on 3 inches.	Tensile Strength. Tons per Sq. In.	Elongation per Cent. on 3 inches.	Oxygen per Cent.	Arsenic per Cent.	Antimony per Cent.	
RR	19·80	14·7	14·33	51·3	0·05	...	...	
A3	19·50	13·0	14·25	43·3	0·058	...	0·2	
A2	19·44	16·7	14·95	46·0	0·054	...	0·29	
AA2	19·55	13·0	14·64	48·3	0·063	...	0·3	
AA1	20·30	6·0	15·16	44·7	0·33	...	0·49	
A	20·16	15·3	14·92	48·7	0·065	0·36	0·2	
Table IIa.								
							Tin per Cent.	Lead per Cent.
L1	18·33	17·3	14·7	53·3	0·023	0·39	...	0·18
T	19·84	14·0	15·48	41·7	0·05	0·37	0·19	...

formation of scale, necessitating the instantaneous treatment in dilute acid for its removal. This superficial "pickling," which aroused criticism, has been proved by the author to be perfectly harmless. However, the removal of scale by means of emery-paper is more effective, and is necessary, in any case, even after pickling. In the train of wash-bulbs, one containing silver nitrate was substituted for the one containing mercuric chloride. Any arsenuretted or antimoniuretted hydrogen from the hydrogen generator is thus arrested.



Fig. 2. Showing absence of "Oxidules" in one part of rod A3. Magnified 200 Diameters. V. Unetched.

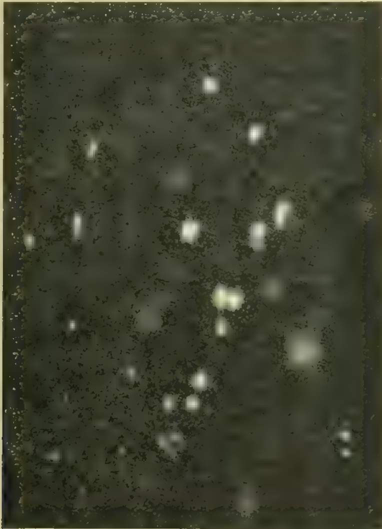


Fig. 3.—Showing Segregated "Oxidules" (Pale Green Spots on Blood Red Ground). Rod A3. Magnified 500 Diameters. V. Heat Tinted.

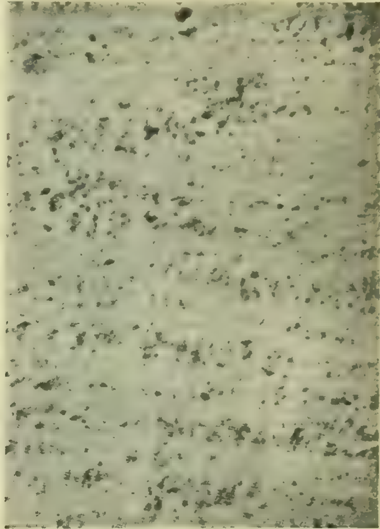


Fig. 4.—Showing Excess of Cuprous Oxide in Rod AA1. Antimony, 0·5 %; Oxygen, 0·33 %. Magnified 150 Diameters. V. Unetched.

Table III.—*Dr. Arnold's Alternating Stress Tests.*

Mark on Rod.	Number of Alternations.		Percentage Increase in Toughess due to Annealing.	Composition				Remarks.
	As Rolled.	Annealed.		Oxygen per Cent.	Arsenic per Cent.	Antimony per Cent.		
RR	118	244	107	0·05	...	...	...	Fracture-line central; silky.
A3	136	210	54	0·058	...	0·2	...	,, ,, eccentric; silky.
A2	116	268	131	0·054	...	0·29	...	,, ,, central; silky,
AA2	118	258	110	0·063	...	0·3	...	,, ,, ,, ,,
AA1	49	138	181	0·33	...	0·49	...	Very broad serrated fracture-line; dry.
A	119	258	116	0·065	0·36	0·2	...	Fracture-line central; silky.
Table IIIa.								
						Tin per Cent.	Lead per Cent.	
L1	169	238	41*	0·023	0·39	...	0·18	Fracture-line central; silky.
T	134	266	98	0·05	0·37	0·19	...	,, ,, ,, ,,

* The abnormal toughness of bar L1 in the cold-worked state as compared with the others is due to the low percentage of oxygen, thus affording further proof of the embrittling influence of cuprous oxide during cold work.

Antimony. — This was determined by several methods, but the method finally adopted for all the rods was that in which pure ferrous sulphate is added after oxidation to a nitric acid solution of 10 grammes of copper (more if only traces of antimony). Ammonia is added in excess; the ferric hydrate carrying down the antimony as basic antimonate of iron. Arsenic is also similarly carried down if present. The precipitate is redissolved in hydrochloric acid, gassed with sulphuretted hydrogen, the mixture of sulphides (in most cases only copper and antimony sulphides) treated with 10 per cent. potassium sulphide to extract the antimony sulphide (Sb_2S_3). The Sb_2S_3 is reprecipitated by acidifying with dilute sulphuric acid, then dissolved in strong hydrochloric acid after boiling and filtering (any arsenic sulphide (As_2S_3) being left behind on filter). Bromine is added, reduction effected by sodium sulphite, and the antimony titrated with potassium bromate.* The author has tried the methods of distillation which depend upon raising the boiling points of the solvent used in order to reach the distillation temperature of antimonious chloride. The methods suffer from the disadvantages of demanding constant attention, and of being expensive in distilling flasks, unless flasks of fused silica ware are used. The author invites discussion on the merits of dis-

* Duncan, "Chemical News," February 1st, 1907.

tillation methods for antimony in copper. Arsenic was determined by distillation as usual.

Preparation of Test Pieces.

(1) Tensile Test Pieces.—Portions of the rods were sawn off, and turned down to ½in. for a gauge length of 3in. full, the 3in. length being marked off exactly. The finished test piece had dimensions as shown on Fig. 1.

(2) Alternating Stress Test Pieces.—These were for Dr. Arnold's testing machine, and 6in. lengths of rod were turned down to ⅜in. diam.

(3) Compression Test Pieces.—Small cylinders were prepared from the rods (⅝in. diam. by 1in.) by facing down in the lathe.

The test pieces were annealed at 800° C. for 15 minutes. The reheating-annealing of the cast ingots is particularly beneficial in the case of antimonial copper, as the solid solution in the cast state is greatly lacking in uniformity. A thorough reheating assists diffusion and produces greater uniformity.

The Mechanical Tests.

On reference to Table II., the outstanding facts are as follows: (1) Antimony raises the tensile strength of "tough-pitch" copper, and slightly lowers the percentage elongation. (2) The annealed rods give results better for purposes of comparison than cold-worked rods before annealing. (3) Where cuprous oxide is in large excess, cold work has a seriously embrittling effect. Rod AA1 has an astonishing percentage recovery of ductility after annealing (over 600 per cent. as compared with less than 300 per cent. in the case of the "tough-pitch" rods). (4) Antimony (0·2 per cent.) has no ill effect on arsenical "tough-pitch" copper.

In Table III. the results of the alternating-stress tests are recorded, and the chief points of interest are as follows: (1) Antimony up to 0·30 per cent. does not decrease the toughness of "tough-pitch" copper, nor does 0·2 per cent. antimony decrease the toughness of arsenical "tough-pitch" copper. (2) Cuprous oxide in excess very seriously lowers the toughness, more so in the rolled than in the annealed rod. (3) Rod A3 shows abnormal behaviour. It will be shown later that this is due to lack of uniformity.

The compression test pieces were crushed down under a steam hammer from cylinders 1in. long by ⅝in. diam. to discs $\frac{5}{16}$in. by 1¼in. diam.

These tests showed that, in the case of the annealed specimens, the quality of the copper in no degree suffers deterioration on account of the presence of antimony. With regard to the unannealed specimens, these all showed signs of the strains previously caused by the cold rolling. They all developed minute incipient cracks round the bulging circumference of the disc, these being most marked in the case of specimen AA1 (rich in cuprous oxide). The excessive embrittling influence of the cuprous oxide was removed by annealing, thus confirming the tensile and alternating-stress tests. The annealed specimen showed no cracking indicative of brittle metal, but one large fissure was developed, corresponding to the inevitable flaw in the rod, due to the original surface depression of the underpoled ingot. This depression had been closed up in the rolling process, causing a hidden longitudinal flaw, which naturally yawned open as the test piece was spread out by the blows from the hammer.

Cold-rolling Tests.

Short pieces of the ⅝in. rods as rolled were sawn off, annealed (20 minutes at 900° C.), and quenched. These were rolled cold into flat strips ⅛in. thick without further annealing. Test pieces RR, A, A2, and AA2 showed no edge cracking whatever. Incipient edge cracking occurred in the case of A3. AA1 was again the worst of all, edge cracking starting when a thickness of $\frac{3}{16}$in. had been reached.

Microstructure.

All the rods as rolled showed a uniform crystalline structure with frequent "twinning." With regard to "oxidules," the appearance of the rods under the microscope differed from one another. They are given in Table IV. The segregation of the cuprous oxide quite explains the abnormal behaviour of rod A3 in the mechanical tests (see Table II. and III.), also the eccentricity of the final fracture line in the alternating-stress tests. Normal rods show a fracture line across the centre of the test piece. Rods which are not uniform yield more to the stresses on their weaker side, and the final fracture line occurs nearer to the stronger side.

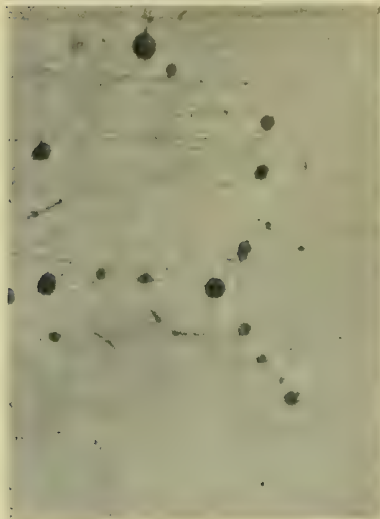


Fig. 5.—Alloy II., Table V. Shows Dark Slate Coloured Antimonial "Oxidules" Antimony, 0·5 %; Oxygen, 0·12 %. Magnified 400 Diameters. V. Unetched.

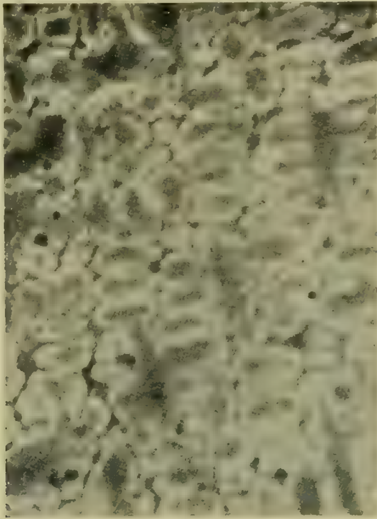


Fig. 6.—Alloy VI., Table V. Antimony, 0·5 %; Oxygen, 0·10 %. Magnified 70 Diameters. V. Etched.

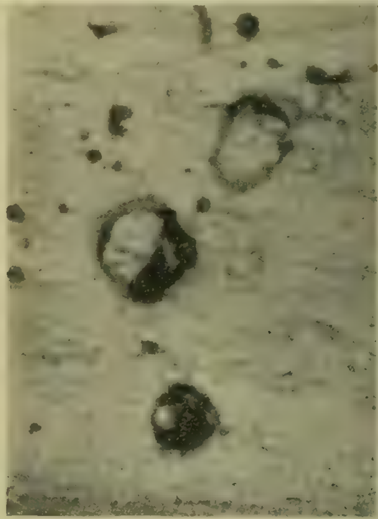


Fig. 7.—Same Alloy as Fig. 6. Magnified 950 Diameters. V. Unetched.

Table IV.

Mark.	Antimony Per Cent.	Oxygen Per Cent.	Appearance under Microscope.
RR	Nil	0·05	Light-blue oxidules (cuprous oxide) uniformly distributed.
A3	0·2	0·058	Dark, slate-coloured "oxidules." Some segregated cuprous oxide (see Fig. 3).
A2	0·29	0·054	Dark oxidules. No cuprous oxide. Uniform.
AA2	0·3	0·063	Dark oxidules. Also cuprous oxide. Uniform.*
AA1	0·49	0·33	Considerable excess of cuprous oxide, accompanied by a few dark "oxidules." In the cast ingot, more than half the field is occupied by copper-cuprous oxide eutectic. During rolling this was broken up and the microstructure shows the parallel trains of "oxidules" (cuprous oxide) in lines following direction of rolling (see Fig. 4).
A	0·2	0·065	Dark oxidules. A little free cuprous oxide.

* Nearly all the "oxidules" in AA2 resemble that shown in Fig. 8. There are one or two isolated "oxidules" similar to that shown in Fig. 9.

On referring back to the rough notes made when preparing the ingots, the following entry was found: "Ingot A3 perfectly level, but poured rather cold." Here, then, possibly lies the explanation of the lack of uniformity in the ingot. A portion of the molten metal (probably the last to enter the mould) was richer in oxide than the remainder, and, on account of the metal being cold, solidification proceeded so rapidly that this oxide had no chance to diffuse uniformly throughout the ingot and was trapped in situ.

Fig. 2 shows the complete absence of cuprous oxide from one area of the specimen, whilst Fig. 3 is typical of the oxide-rich area. In order to obtain better contrast for photographing, the specimen was heat-tinted for this photomicrograph. The cuprous oxide showed up as pale-green spots on a blood-red field (white spots on a black background in Fig. 3). Before heat-tinting, the "oxidules" appeared pale-blue on pink background of copper, a combination difficult to reproduce effectively by photography.

THE STRUCTURAL CONDITION OF ANTIMONY IN "TOUGH-PITCH" COPPER.

A number of experiments were made by adding to copper (from which all oxygen had been carefully excluded) metallic antimony alone, antimonious oxide (Sb_2O_3) alone, and metallic antimony plus cupric oxide. The details are given in Table V.

TABLE V.

No.	Antimony Per Cent.	Oxygen Per Cent.	Nature of Impurity added.
I.	0·5	Nil	Metallic antimony.
II.	0·5	0·12	Metallic antimony and cupric oxide.
III.	0·5	0·25	,, ,, ,, ,,
IV.	0·1	0·12	,, ,, ,, ,,
V.	0·5	0·10	Antimonious oxide.
VI.	0·5	0·10	,, ,,
VII.	4·03	0·97	,, ,,

In alloy I. most of the antimony was in solid solution, and etching revealed the usual "core" structure, in the light antimony-rich fringes of which a very little free Cu_3Sb was visible. This constituent, the composition of which is given by Hiorns, is very pale-blue in colour (paler than cuprous oxide), and is best seen before etching. In alloy II. the oxygen appeared not as cuprous oxide, but as dark slate-coloured "oxidules." Caustic soda or potash should not be used to remove grease from the surface of the specimen, as it attacks the antimonial "oxidule," leaving only a pit which appears black under the microscope. These antimonial "oxidules" are shown in Fig. 5, and occur in all the other alloys, whether cuprous oxide is in excess or not. Wherever oxygen occurs in excess of that demanded by that part of the antimony which is not in solid solution, it exists as pale-blue cuprous oxide, which forms a ternary eutectic with the solid solution and the antimonial "oxidules."

Fig. 6 shows the solid solution of antimony in copper (dark-etching "cores" with light antimony-rich fringes) surrounded by eutectic. The constituents of the eutectic under higher powers show peculiar behaviour in their relative disposition. Either the slate-coloured antimonial constituent or the light-blue cuprous oxide forms here and there as a crescent or circlet enclosing a globule of the other constituent.

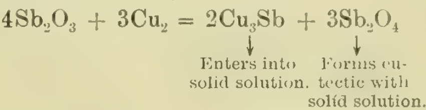
In Fig. 7 are seen two of these circlets of cuprous oxide, the centre one enclosing both copper (light half) and the antimonial constituent (dark half). In the lower portion of the micrograph a dark antimonial "oxidule" is seen, and several smaller ones are dotted here and there in the upper portion of the field.

Fig. 8 illustrates an area of the same specimen showing another composite "oxidule," the antimonial portion forming the enclosing crescent in this case, the cuprous oxide globule being enclosed.

As to the true composition of the antimonial constituent, the author can make no definite statement. In fact, its composition seems variable; in some cases having a definitely duplex structure as shown in Fig. 9. This shows a slate-coloured "oxidule" containing numerous particles of a blue colour (probably cuprous oxide). In other cases the "oxidules" contain coppery streaks which may possibly be the metallic reduction product of a reaction between a reducing gas such as carbon monoxide on cuprous oxide. These coppery streaks are sometimes seen in the centre of cuprous oxide "oxidules" in ordinary commercial copper, and there may be some connection between them and the gases present.

Possibly the checking influence of antimony on "spewing" may find an explanation in the absorptive power of its "oxidules" for gases, but the author is unable to support this explanation. It seems to be clear that the antimony exists in the higher state of oxidation (Sb_2O_4), because in alloy VII. (Table V.), although the antimony was added in the form of antimony trioxide (Sb_2O_3), it split up into antimony—which formed Cu_3Sb, and partly entered into solid solution—and the slate-coloured constituent already described. Whether the latter is Sb_2O_4 alone, or a compound of Sb_2O_4 with Cu_2O (antimonate), whether it is capable of merely dissolving copper or Cu_2O, or whether, if this be true, it deposits the dissolved substance when cooling, further research may show.

An examination of alloy VII. under the microscope showed no Cu_2O, but such an amount of free Cu_3Sb in addition to that which was in solid solution as would represent, roughly, about one-third of the antimony present. The author suggests the following reaction:—



$$4Sb_2O_3 + 3Cu_2 = 2Cu_3Sb + 3Sb_2O_4$$

For antimonial copper, it would seem that the less antimony which is allowed to enter into solid solution (*i.e.*, the more which exists as "oxidules") the higher will be the electrical conductivity.

When oxygen is present, as much free Cu_3Sb is converted into "oxidules" as the oxygen will account for. In the case of bar A1 (see Table II. and Fig. 2), so much oxygen had been

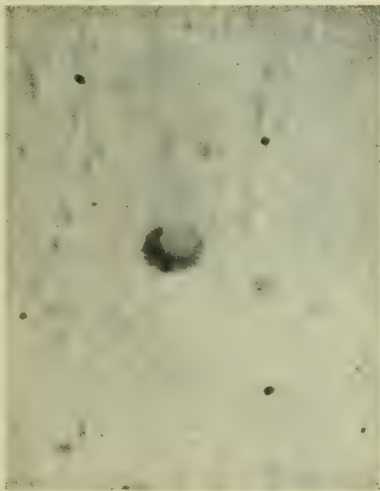


FIG. 8.—SAME ALLOY AS FIG. 6. MAGNIFIED 900 DIAMETERS. V. UNETCHED.

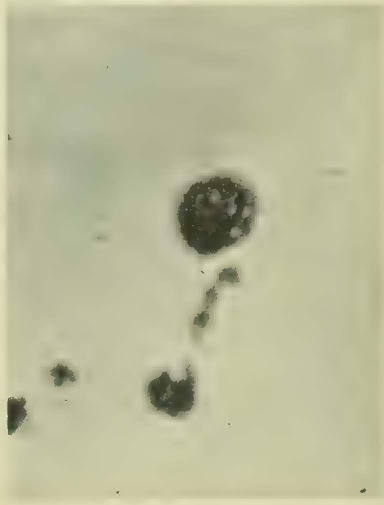


FIG. 9. SAME ALLOY AS FIG. 6 MAGNIFIED 900 DIAMETERS. UNETCHED.

TABLE VI.

Mark on Ingot.	Antimony Per Cent.	Oxygen Per Cent.	Remarks.
A5	0·5	Undetermined.	Under pitch. Forged perfectly.
A5	0·5	0·13	Up to pitch. Forged perfectly. Bent double cold.
A6	1·0	Undetermined.	Under pitch. Forged perfectly.
A6	1·0	0·25	Up to pitch. Forged fairly well. Incipient cracking. Bent double cold.
A7	1·0	Nil.	Decidedly red-short. Free Cu_3Sb discernible under the microscope.

removed by poling that, in all probability, some free Cu_3Sb separated out.

In order to show whether, by increasing the oxygen in order that all the antimony not in solid solution would exist as harmless "oxidules," the author made the foregoing experiments.

Small ingots were cast, particulars of which are given in Table VI. Ingots A5 and A6 were forged at a red heat when "under pitch," then remelted, and brought up to pitch. All three ingots were reheated side by side, and forged at a red heat. The results are given in Table VI., and show that it is possible to forge copper hot, even with 1 per cent. antimony, if sufficient oxygen be present to prevent the occurrence of free Cu_3Sb.

Experiments with Tin and Lead.

These experiments, whilst far from being sufficient, are of such interest, and the possibility of their continuance so uncertain at present, that the author has decided to place them on record. The ingots were prepared in exactly the same way as the antimonial ingots, and were rolled and tested at the same time and under exactly similar conditions.

Influence of Lead on "Poling" Operation.—From the behaviour of trial ingots the author proved that: (1) Lead (in the proportions used) caused "tough-pitch" arsenical copper ingots to "sink" in the moulds. That is to say, an ingot which would otherwise have had a level surface had a longitudinal surface depression after the addition of lead. (2) By "poling" the metal in order to produce an ingot with a level surface, so much oxygen was removed that in one case (ingot L2) the ingot was so "red-short" as to be shattered during the first pass through the rolls at a red heat (see Fig. 1). There were also strong indications that with the smaller percentage of lead (0·18 per cent.) it would be possible to carry "poling" so far (without the ingot spewing) as to produce "red-shortness."

In fact, ingot L1 was produced by remelting the rolled strip of a previously prepared ingot, which had shown edge cracking at a red heat. The oxygen, unfortunately, was not determined in this strip before remelting, but it was probably lower than in L1. In Table VII. the analyses of the ingots and a record of their behaviour appear.

Influence of Tin.—The influence of tin seems to be to harden arsenical copper for hot and cold working, and to raise the tensile strength more than any other of the elements tried. The record of the mechanical tests appears in Table IIa and IIIa. Apart from causing a peculiar, irregular bulging at the circumference of the hammered annealed discs, the lead and tin specimens showed no difference of behaviour from the other specimens in the crushing-down tests.

Table VII.

Mark on Ingot.	Oxygen Per Cent.	Arsenic Per Cent.	Lead Per Cent.	Tin Per Cent.	Appearance of Ingot.	Behaviour in Rolling.
L1	0·023	0·39	0·18	Nil	Dead level.	Very good.
L2	0·012	0·38	0·35	Nil	..	Smashed at first pass.
T	0·05	0·37	Nil	0·19	Very slight depression. A few pin-holes near surface.	Very good. Forged hard. Good smooth surface.

Conclusions.

(1) Antimony up to 0·5 per cent. has no detrimental influence on the hot-forging qualities of "tough-pitch" copper free from other impurities. It is even possible successfully to forge copper containing 1 per cent. antimony if sufficient oxygen be present.

(2) In copper which has been "overpoled," antimony tends to mitigate the phenomenon of "spewing" during solidification.

(3) "Tough-pitch" arsenical copper (0·4 per cent. arsenic) is slightly hardened for hot-rolling by the presence of antimony (0·2 per cent.), but, otherwise, its mechanical properties are slightly improved.

(4) The mechanical properties of "tough-pitch" pure copper after rolling and annealing are but little altered by small additions of antimony. The tensile strength is slightly raised, and the elongation is lowered. The slight gain in toughness is probably traceable to the greater soundness of the cast ingot.

(5) With regard to the structural condition of antimony in "tough-pitch" copper, it exists in two forms: (*a*) Partly in solid solution (probably as dissolved Cu_3Sb). (*b*) Partly as an insoluble compound with oxygen (slate-coloured "oxidules").

Oxygen in excess exists as cuprous oxide (light-blue "oxidules"). The latter, together with the antimonial "oxidules," form a ternary eutectic with the solid solution.

(6) The addition of lead to pure copper or arsenical copper causes the surface of a "tough-pitch" ingot to sink during solidification. Further poling with the object of obtaining a level surface is attended by the risk of rendering the metal "red-short." Like antimony and arsenic, lead tends to check "spewing."

(7) The mechanical properties of arsenical copper (0·4 per cent. arsenic) at normal temperature are little affected by the addition of lead (0·2 per cent.).

(8) The addition of tin (0·2 per cent.) to "tough-pitch" arsenical copper is attended by an increase in hardness during hot and cold rolling, and an increase in tensile strength. The elongation is correspondingly lowered, but the toughness is unimpaired.

Finally, the author wishes to express his indebtedness to Mr. C. H. Eden, of Messrs. Vivian & Sons, Swansea, for permission to have the ingots rolled; to Mr. W. S. I. Bray (manager of Messrs. Vivian & Sons' Works at Margam) for his interest and assistance; to Prof. Arnold, D.Met., for invaluable aid in making the alternating-stress tests; and to Mr. T. G. Jones, M.Sc., Head of the Engineering Department, Swansea Technical College, for his kindness in carrying out the tensile tests on the 30-ton Buckton testing machine in his Department.

THE TRANSMISSION OF HEAT.

In the course of a paper read by Mr. C. H. Lander, M.Sc., and Prof. J. E. Petavel, F.R.S., before the British Association, the authors described an experimental investigation of the transmission of heat from heated metal cylinders to the surrounding air, which has a direct bearing on the lagging of steam pipes; the temperatures, however, ranged up to 2,000° Fah., and the pressure in the air enclosure was varied from atmospheric up to 3,000lbs. per square inch. In the case of steam pipes, the heat loss per hour per square foot per degree

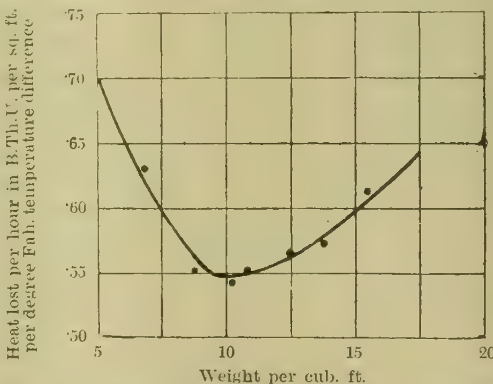


Fig. 1.—Effect of Density of Covering on Heat Loss.

Fah. difference of temperature was measured, with the following results:—

Bare steam pipes containing saturated steam at atmospheric pressure and at 100lbs. per square inch gauge pressure, external atmosphere at 60° Fah.:—

External Diameter of Radiator. Inches.	Heat loss per hour in B.Th.U. per square foot per degree Fah. At Atmospheric Pressure.	At 100lbs. per square inch.	Conduction only, taking K=0·144.*	
0·2	3·94	6·0	0·39	Assuming layer of air to be 4in. thick round radiator.
1	3·00	4·0	0·13	
2	2·55	2·8	0·089	
3	2·30	2·4	0·074	
5	2·05	2·1	0·060	
12	1·97	—	0·047	

* The constant K is given in B.Th.U. per hour per square foot of surface per degree Fah. temperature difference for a layer 1in. thick.

Under the conditions described, the loss of heat is mainly due to convection. In the case of a pipe, for example, 1in. diam., containing steam at atmospheric pressure, the loss by radiation is 0·44 or 15 per cent., and by conduction 0·13 or 4 per cent., so that 18 per cent. is dissipated by convection; at 100lbs. per square inch the loss by convection would be about 80 per cent. If the surface of the metal were machined the loss by radiation would be halved, and if it were polished the loss would be reduced to one-quarter.

As all lagging materials are better heat conductors than air, they increase the loss due to conduction; it is necessary, therefore, to arrange them loosely, so as to subdivide the air space surrounding the pipe as perfectly as possible with the least amount of solid material. The lagging can, however, be too loosely packed, as will be seen in Fig. 1, which shows the effect of slag wool under various conditions as regards density of packing. The best result was obtained when the solid material occupied one-fourteenth of the total space; the conduction loss was then increased from 0·13 to 0·40, but (assuming radiation to be zero) the convection loss was reduced from 3·2 to 0·14, the total loss being one-seventh of that observed with the bare pipe. The loss by radiation per square foot from small pipes diminishes rapidly as the diameter increases, but above 4in. diam. it becomes nearly constant.

Alterations to the "Olympic."—The White Star liner "Olympic" arrived at Belfast on Thursday last week to undergo extensive alterations, which will cost £250,000. The work will occupy from four to six months. The repairs will be carried out by Messrs. Harland & Wolff.

Workman Electrocuted. — A foreman erector at the product works at Dinnington Main Colliery was electrocuted on the 9th inst. Deceased, along with another man, was erecting gas purifiers at the Dinnington Main by-product works. He was trying to unfasten the guide rope connected with the derrick they were using, when the guide rope came in contact with a live wire.

A Fast Airship.—The new naval airship "Baby" was tested a few days ago at Farnborough, and attained such a remarkable speed that it is claimed for her that she is the fastest airship in Great Britain. As the name indicates, the airship is of diminutive proportions, being only one-half the capacity of the Army airship "Beta," and one-tenth that of the ill-fated "Mayfly," which was wrecked at Barrow. Mr. E. T. Wilson, of Cardiff, constructed her, with the exception of the engine, which is French. The airship carries a crew of two—the observer and the pilot. She developed a speed of between 50 and 60 miles an hour.

A Large Zoelly Steam Turbine.—Messrs. Escher Wyss & Co., of Zurich, have recently delivered to the Rheinisch-Westfälischen Electric Generating Station, in Essen, one of the largest steam turbine sets contained in one casing that has been built up to the present time. This turbine is designed to develop 22,500 h.p., effective, under normal continuous working, and at a speed of 1,000 revs. per minute, the initial steam pressure being 150lbs. per square inch above atmosphere, and the steam temperature 572° Fah. before the stop valve, and exhausting to a vacuum of 27½in. This turbine can develop 28,000 h.p. under constant work, and as much as 30,000 h.p. for short periods. The generator rotor, which is of the Siemens-Schuckert type, is connected to the turbine shaft by means of a rigid coupling, and weighs 60 tons.

Railway Electrification.— The directors of the Lancashire and Yorkshire Railway Company have made arrangements for the electrification of a further section of the line from Liverpool, between Town Green and Ormskirk, and the work is to be started immediately. The company have invited tenders for the construction of buildings for an electric sub-station at Ormskirk on the east side of the present railway station, to be used in connection with the generating station at Formby. In the system adopted the power is generated at Formby at 7,500 volts 3-phase, and is delivered by underground cables to the sub-stations, where it is converted to direct current at 620-630 volts, at which pressure it is fed to the trains by a third rail. The company are at present engaged in laying down the third set of conductors on the eastern lines between the Exchange Station, Liverpool, and Sandhills.

INDUSTRIAL AND TRADE NOTES.

Electrical Driving of Textile Mills.—The Tootal Broadhurst Lee Company, Ltd., are converting their mills at Bolton to electrical driving.

New Asbestos Factory.—Messrs. Turner Brothers, Limited, asbestos and belting manufacturers, of Rochdale, have acquired land in the Trafford Park Estate on which they are about to erect large works. Although their establishment at Rochdale was capable of being extended considerably, Messrs. Turner have selected Trafford Park because of the facilities for direct communication with sea going vessels.

Cleveland Blastfurnacemen's Wages. – The net selling price of No. 3 gmb Cleveland pig for the quarter ended September 30th last has been certified at 54s. 5·64d. per ton, as compared with 50s. 0·43d. per ton for the previous three months. There was thus an advance in prices of 4s. 5·21d. per ton in the third quarter of the year, this causing an advance in blastfurnacemen's wages of 5½ per cent., which brings wages from 22½ per cent. above the standard to 28 per cent. above the standard.

Industrial Exhibitions. — At the International Exhibitions Conference, opened at Berlin on the 8th inst., Herr von Kiderlen-Waechter, Secretary of State for Foreign Affairs, pointed out that the number of exhibitions was growing from year to year, and that in consequence of their frequency a certain "exhibition lassitude" was beginning to be noticeable in industrial circles. This condition of things was not without danger. The conference had now to try and formulate some general rules which would prevent international exhibitions from following on each other's heels at too short intervals.

Electricity for Ship Repairing.—Messrs. Harland & Wolff, Ltd., have arranged with the Bootle Corporation Electricity Works to take a supply of electricity for power and lighting for the new ship repairing works which they are equipping at the North Docks, leased from the Mersey Docks and Harbour Board. The original installation will comprise electric motors to the extent of over 1,500 h.p., working tools and machinery on the individual drive system. Small tools will be group-driven. The lighting will be carried out with flame arc lamps connected in groups on 220 volt circuits.

Advance in Scotch Oil Prices.—The Scotch mineral oil companies have followed the lead of the Americans by advancing prices of their lubricating and fuel oils 12s. 6d. to 15s. per ton. The Scotch companies are now in a much stronger position than they were a year ago, owing to the slackening of American competition, but in a great measure to the increased number of uses to which oil has been adapted. Since the beginning of this year No. 1 burning oil has risen from 5¼d. to 8½d. per gallon; naphtha, from 6½ to 9½d. per gallon; and semi refined wax from 2d. to 2¼d. per pound; while lubricating oils are £3. 10s. per ton higher than the lowest prices reached during the depression.

Coal Miners' Wages.—The English Federation Board has applied for a 5 per cent. advance of wages for all persons employed in the mines, and for those engaged in manipulating the coal on the surface in the federated area, which embraces Lancashire, Yorkshire, Derby, Nottinghamshire, Warwickshire, Leicestershire, North Staffs., and North Wales. A meeting of the Coal Conciliation Board which covers this area was held in London on the 9th inst. to consider the proposal. At the conclusion of the meeting it was stated that no information could be given as to the decision until it had been communicated to the employers at a meeting of the Coal Conciliation Board. After that meeting a further conference will be held to receive the report of the representatives of the men on the board.

The Trade of India.—A Blue Book has just been published, reviewing the trade of India during the year 1911-12. This shows that India's imports rose from 86·24 million pounds in value to 92·38 millions, while the exports rose from 139·92 millions to 151·83 millions, the total trade thus increasing from 226·16 millions to 244·21 millions, an increase of 8 per cent. Exports representing 55·4 per cent. of the total trade showed an increase of 9·7 per cent. on the previous year, and imports an increase of 13·6 per cent. Trade with Europe represented 64·6 per cent. of India's total exports. Business with the United Kingdom increased by 10¼ million sterling, or 11·7 per cent., and the trade in all British possessions, representing 52·3 per cent. of the whole trade, showed an increase of 7·4 per cent.

Belfast Shipyard Engineers' Wages.—As a result of the negotiations which have been conducted between the representatives of the Belfast branch of the Amalgamated Society of Engineers and Messrs. Harland & Wolff and Messrs. Workman, Clark, & Co. during the past month, an increase of 1s. per week has been

granted to the engineering staffs at both of these shipbuilding yards. The men asked for an advance of 2s. per week, so as to bring their wages up to 41s., and the employers decided to give half of the suggested advance now and the other half on March 1st, the latter being subject to the condition that a three years' agreement would be signed. A meeting of the men affected—between 1,500 and 2,000—was held on Saturday last to consider the masters' proposal in regard to the agreement question. The proceedings were private, and no report was issued to the press.

Russian Iron and Steel Trade.—According to official statistics the upward tendency in the Russian iron trade, which was manifest in 1911, continued during the first four months of the present year. Pig iron aggregating 1,330,000 tons was produced from January to April, 1912, against 1,128,000 tons during the corresponding period in 1911. It is noteworthy, too, that simultaneously with increased production there has been a constant diminution in the stocks held at smelting works. On April 1st, 1910, the stocks of pig iron were estimated at 583,500 tons, on May 1st, 1911, at 377,000 tons, and on May 1st, 1912, at 362,000 tons. Not only have blastfurnaces been kept working at greater pressure, but the number of furnaces is steadily increasing. At the end of March this year 151 furnaces were working, as against 138 12 months previously. This satisfactory state of trade is attributed to the increased requirements for railway works, building trades, machinery and engineering industries, &c.

Personal.—Mr. W. T. Davies, who is at present serving as constructor at the Admiralty, London, has been appointed local shipbuilding director of Vickers, Ltd., at Barrow, vacant by the retirement of Mr. J. H. Boolds. Mr. Davies, who is 45 years of age, served his apprenticeship at Portsmouth Dockyard. Afterwards he was transferred to the Royal Naval College, Greenwich, for the higher courses in training in naval architecture. In 1890 he was appointed member of the Royal Corps of Naval Constructors at Portsmouth, and was promoted to the rank of Constructor in 1902.—Mr. F. E. W. Coller has been appointed manager of Elswick Shipyard, Newcastle-on-Tyne, in succession to Mr. G. J. Carter, late manager, who has recently taken up the appointment as managing director to Messrs. Cammell, Laird, & Co., Birkenhead. For many years Mr. Coller was assistant to Mr. Carter, then at Wallsend Slipway and Engineering Company, Wallsend.

Vickers, Ltd.—Evidence of the extraordinary activity in the shipbuilding industry is afforded in the case of Messrs. Vickers, Ltd., of Barrow, who have in hand the construction of no less than 23 vessels for the navies of different nations. These vessels include three super Dreadnoughts: The "Delhi," for the British Admiralty; the "Mehmed Rashad V.," for the Turkish Government; and the battle-cruiser "Kongo," for the Mikado's Government. Three of the "Town" class of light-armoured cruisers for the Admiralty, three monitors for the Brazilian Government, a motor-boat for the Admiralty, a floating dock for the Argentine Government, and last, but not least, 13 British submarines. In the engineering department orders are also numerous, the firm having in hand or in course of construction engines of 400,000 s.h.p. The gun-mounting department of the works is also busy, and there is quite a throng of orders for the home and foreign governments.

Shipbuilding Boom.—The present activity in the shipbuilding yards of Great Britain is illustrated by the returns compiled by Lloyd's Register of Shipping for the quarter ended September 30th. The returns, which only take into account vessels whose construction has actually begun, show that, excluding warships, there were 505 vessels, of 1,846,829 tons gross, under construction in the United Kingdom at the close of the quarter. The figures are the highest ever recorded in the society's quarterly returns, which extend back to 1882. The tonnage now under construction is about 73,000 more than that which was in hand at the end of the preceding year, and exceeds by 400,000 the tonnage building a year ago. In addition, 82 warships with a tonnage of 494,538 were under construction. All but 12 of these were British, and consisted of eight battle-ships, four battle-cruisers, eight protected cruisers, two third-class cruisers, 34 torpedo-boat destroyers, and 14 submarines. Against the immense figures for the United Kingdom may be placed (excluding warships and vessels under 100 tons) Germany's 101 (467,763 tons), United States' 85 (215,295 tons), and France's 28 (119,618 tons).

Engineers' Wages in the Manchester District.—The wages question in the engineering industry of the Manchester district, in which some 13,000 workers altogether are concerned, was discussed on the 9th inst. at a conference between the committee of the Manchester Engineering Trades Employers' Association and the representatives of the several trade unions. The engineers had made application for an increase of 3s. a week in the wages of day men, and of 7½ per cent. in the rates of pay for piece workers. A meeting of the employers, preliminary to the conference, was held on the previous Tuesday, but no information as to its decision on the points in question was communicated to the press. It was, however, regarded as probable that the employers would offer an advance of 1s. a week in wages for the one class of worker and 2½ per cent. in rates of pay for the other. Another section of workers in the engineering industry who are asking for advances of wages is made up of semi-skilled men and labourers. Advances have been asked for by the General Labourers' National Council for all men whose wages are 28s. or less. The increases which have been asked for are 4s. for men who are now paid 20s. to 22s. a week, 3s. for men with 23s. to 25s., 2s. for men with 26s. to 28s., and 7½ per cent. on piece rates.

Geared Turbine Vessel for India.—There was launched on Saturday last, from the yard of Messrs. A. & J. Inglis, Pointhouse, the turbine steamer "Curzon," built for the South Indian Railway Company. The "Curzon" is the first of three sister ships which Messrs. Inglis are building. The steamers have a length overall of about 260ft., a breadth of 38ft., and a depth to the promenade deck of nearly 19ft., and their gross tonnage will be rather less than 700. The propelling machinery will consist of two sets of geared turbines of the latest Parsons type, one high pressure, and one low pressure being coupled to each of two shafts by means of machine-cut gears, each shaft driving one of the twin screws. This gearing has been made by the Parsons Marine Steam Turbine Company to the order of Messrs. Inglis. The revolutions of the turbines will be about 3,000 per minute, which will give a high turbine efficiency. By means of the mechanical reducing gear, the propellers will revolve at a much less speed, and so secure greater propulsive efficiency. In each low-pressure turbine casing an astern turbine of high power is incorporated. The boilers are of the Yarrow type. Arrangements will be made for burning either Indian coal or oil fuel, as may be decided later.

The Construction of Diesel Engines.—No fewer than five engineering firms on the Clyde are now in a position to make Diesel oil engines for the largest class of ocean-going ships. In the first place the Burmeister & Wain Company, registered some time ago in London, have purchased, from Messrs. Harland & Wolff, the engineering workshops in Glasgow of the London and Glasgow Engineering and Shipbuilding Company. All the resources of this establishment will be devoted exclusively to the manufacture of Diesel engines; the other concerns on the Clyde making these oil engines do so merely as a department of a general marine engineering and shipbuilding business. At Port Glasgow, Diesel oil engines on the Carel design are made by the Clyde Shipbuilding and Engineering Company. At Dalmuir, Messrs. William Beardmore & Co. are licensees and makers of the Diesel oil engine. They hold the joint license from Messrs. Carels Frères, of Ghent, and the Diesel Engine Company, London. Another shipbuilding firm, Messrs. Alex. Stephen & Co., of Linthouse, Glasgow, hold the Diesel license, and so also does a Greenock firm of shipbuilders. While the Clyde is certainly taking the lead in this country in the manufacture of oil engines for ocean-going ships, the most extensive factory will be that now under construction at Ipswich for the Consolidated Diesel Engine Manufacturers, London. This will be the first large factory in Great Britain devoted exclusively to the making of these oil engines, both for ship propulsion and for stationary purposes. A large site is being covered by workshops, and it is anticipated that early next year the establishment will be in full working order.

Prevention of Accidents on Railways.—At the Railwaymen's Conference, recently held at Dublin, Mr. J. T. Robinson (Tyne Dock) proposed: "That this Congress, being of opinion that many of the accidents to the employés on the railways are due to understaffing, and consequent hustling methods, to dangerous processes, to insufficient lighting, to the slow adoption of side brakes, and to the non-adoption of automatic couplings, urges upon the Government to strengthen the administration of the Prevention of Accidents Act, 1900, by the appointment of additional inspectors for the purpose of enquiring into dangerous methods of working and working processes, in order that steps may be taken to prevent accidents, instead of waiting until they occur and making enquiries afterwards. We also emphatically reaffirm our opinion that representatives of this society should be allowed to visit all scenes of accidents and be given reasonable opportunities for inspection." He said they found on the railways at the present time that companies were trying to work the traffic with as few hands as possible. Since the Hours Act came into force the railway companies had adopted a new scheme by which the men were worked for a day of ten or eleven hours, and then brought on again to work after nine hours' rest. This was a worse system than the old one of long hours and of continuous service. There were men on the North-eastern Railway who were working 60, 70, and 80 hours a week, and he believed a similar state of things existed on the Midland Railway. A frequent cause of accidents to railwaymen was the

unlighted colliery siding. In recent years there had been a large increase in the number of railwaymen who were injured. In 1901 14,740 were injured, but in 1911 the number had risen to 27,848. He contended that practical railwaymen ought to be appointed to inspect goods yards sidings, and make recommendations to the company for safe working. The resolution was unanimously carried.

"Willcox-Penberthy" Cellar Drainer. — There has recently been placed on the market by Messrs. W. H. Willcox & Co., Ltd., 38, Southwark Street, London, S.E., the "Willcox-Penberthy" cellar drainer, which is particularly adapted for use in pits, sumps, cellars, tanks, settling basins, or wherever it is desired to keep water or other liquids from going above a certain level. It consists of a water pressure ejector of high capacity, automatically operated by a float-controlled, quick-opening-and-closing valve. This valve is never partially opened; it cannot leak, and allows the ejector to give its greatest efficiency by working to full capacity. The float arms are slotted where they connect to the valve lever—this prevents the ejector from operating until the water has raised the float up to the highest point, and, as the water is ejected, they travel down the length of these slots before the weight of the float affects the valve. This allows the machine to work for longer periods and not so often, thus preventing considerable wear and the leakage and dribbling of water, as is so common in the majority of drainers. To enable the installation of this drainer in small holes, or sumps, it has been made as compact as possible. The float, instead of being round, is flat on the top; it has more buoyancy and occupies less space than would a round float at the same diameter. Space is further economised by building the float around the suction pipe. This patented feature has the added advantage of being rigid, and overcomes all the trouble of the common loose float. The balance of the drainer is built directly above the float; this not only keeps the whole machine in as small a space as possible, but also keeps all working parts, with the exception of strainer and float, above the water, thus preventing corrosion or the exterior parts becoming clogged up by deposits of slime, dirt, or sediment. The interior parts are prevented from coming into contact with any foreign particles by the special strainer, which is so constructed that instead of the water being drawn directly upward, it is taken in at the sides, allowing all sediment to collect under the strainer without being disturbed by the force of the suction. A foot valve is also provided inside the strainer, which closes the instant the drainer ceases operating, holding all water in the pipes, all primed for starting instantly, at the next filling of the sump.


"WILLCOX-PENBERTHY" CELLAR DRAINER.

Parsons' Marine Steam Turbine Company.—The report of the directors of the Parsons' Marine Steam Turbine Company, to be presented at the 15th annual general meeting of the shareholders on October 22nd, states that the application of geared turbines to marine propulsion, on the system initiated by the company, has made great progress during the year, having regard to its novelty and recent introduction. No less than 15 vessels of various types, with an aggregate of over 100,000 h.p., are now built or building with geared turbines. The expenditure on experiments has been exceptionally large, due, in part, to work bearing on the development of geared turbines. Experience with the "Vespasian" continues to be entirely satisfactory, and the results obtained in that vessel have had considerable influence on the extended use of gearing. Experimental research on the causes influencing the efficiency of screw propellers has been continued during the past year. Valuable results have been obtained, and the best lines for further experiment have been ascertained and will be utilised. The enquiry has a direct and important bearing on the future of economic propulsion by means of steam turbines, and will prove of service to licensees in dealing with designs going beyond precedent. The "combination" system, in which reciprocating engines are associated with low-pressure turbines, continues to find favour in certain classes of passenger steamships. Important vessels engined on this system are now being built by Messrs. Denny and by Harland & Wolff, Ltd. Up to the present time the total horse-power of marine turbines of the Parsons type, completed and under construction in the works of the company and of licensees, as well as in the works of the continental subcompanies, and of licensees of Parsons' Foreign Patents Company, Ltd., amounts to about 8,500,000 h.p.—an increase during the year of about 2,100,000 h.p. Of this total horse-power, nearly 7,200,000 h.p. are, or will be, employed for the propulsion of warships, and over 1,300,000 h.p. in vessels of the mercantile marine and yachts. At present the total number of vessels built and building for the Royal Navy and Colonies, with Parsons turbines, is 202; the total horse-power is about 3,700,000. The profits for the year, after providing for depreciation, &c., amount to £27,711; the amount brought forward from the last balance sheet is £17,508. The total amount available for distribution is thus £45,220. This the directors recommend should be appropriated as follows: (1) In payment of a dividend at the rate of 10 per cent. per annum (free of income-tax), of which an interim dividend of 5 per cent. for the six months to December 31st, 1911, was paid on January 27th last, absorbing £21,128; (2) in payment of a bonus of 2½ per cent. (free of income-tax), £5,282, £26,410; (3) leaving as a balance to be carried forward £18,810.

TEST OF MINERS' SAFETY LAMPS.

A SUPPLEMENTARY memorandum has been issued by the Home Office in view of questions which have been raised by manufacturers who desire to submit safety lamps to be tested. It is pointed out that makers should supply the wicks, and they may, if they desire, supply the oil, for the testing of their own lamps. The apparatus necessary for operating the locks of lamps submitted for testing (including magnetic and compressed air locks) must be supplied by the maker. A temporary exception will be made from the rule as to lamp pillars. Lamps now in use if they conform to an approved type in all respects, except that they have only four pillars, may continue to be used for a period not exceeding three years from January 1st next. The rule requiring double gauzes will not be applied to lamps now in use for a period of two years from January 1st next. If a lamp submitted for testing fails to pass the "tests of glass" the makers will be allowed to submit the same lamp for re-testing with a different glass on payment of an additional fee of £2. Slight variations in the form of a lamp (*e.g.*, improvements in the locking devices) may be made without the lamps being re-tested, providing the testing officer is satisfied they are of such a nature as not to affect the requirements prescribed for the test. A lamp containing any such variation may be submitted to the testing officer, who will examine the lamp and decide whether or not the variation is of such a nature as to render a fresh test necessary. The fee for such examination is £2, payable in the same way as the fee for the test. If a fresh test is found to be necessary, this fee may be deducted from the fee for the fresh test.

Institution of Electrical Engineers (Manchester Section).—The new session of the Manchester local section of the Institution of Electrical Engineers will be opened on November 1st at the Midland Hotel, Manchester. The chairman, Mr. A. A. Day, will, we regret to state, be unable, from reasons of health, to be present and read his address, which, however, will be read by the vice-chairman, Prof. E. W. Marchant. A smoking concert will follow the address. During the session a number of interesting papers are down for reading, which include the following: November 5th, "The Turbo-Converter: A High-speed, Direct-current, Generating Unit," by Mr. F. Creedy; November 19th, "Earthed v. Unearthed Neutrals on Alternating-current Systems," by Mr. J. S. Peck; December 3rd, "Some Problems in Traction Development—Street Railway Feeding Networks," by Mr. J. G. Cunliffe and Mr. R. G. Cunliffe; December 17th, "Electric Welding," by Mr. P. Bucher; January 14th, 1913, "Starting and Speed Control on Induction Motors," by Mr. F. C. Aldous; January 28th, "The Use of a Large Lighting Battery in connection with Central Station Supply," by Mr. F. H. Whysall; February 11th, "Advertising Electricity," by Mr. H. C. Palmer; February 25th, "Some Recent Developments in the Manchester Street Lighting," by Mr. S. L. Pearce and Mr. H. A. Ratcliff; March 11th, "Self-starting Synchronous Machines," by Dr. E. Rosenberg; April 1st, "Electric Driving of Textile Factories," by Mr. W. Browning; April 8th, annual general meeting and lecture by Prof. E. Rutherford.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Fuel briquetting plants. Rigby & Testrup. 14624.
Treatment of phosphate ore and the obtaining of nitrogen therefrom. Wallace & Wassmer. 14631.
Carburetters for internal-combustion engines. Torrens. 14749.
Valve-operating means for internal-combustion pumps. Siemens-Schuckert-Werke. 14753.
Double-acting internal-combustion engines. Pierard 16741.
Drilling and boring machines for mining and quarrying. Teakel. 17662.
Signalling arrangements for railways. Dalen. 18780.
Hydraulic production of power by the direct operation of combustible gases. Coster. 18821.
Speed-reducing or speed-multiplying gears. Bronner & Quick. 18957.
Reversible rolling mills. Gatta. 20303.
Aeroplanes. Sugden. 20722.
Treatment of iron or steel for the prevention of oxidation or rust. Rudge-Whitworth, Ltd., and Heatcote. 20798.
Rolling mills. Gatta. 20971.
Process of applying deposits of metal or metallic compounds to surfaces. Schoop. 21066.
Rotary engines. Carbone. 21077.
Rolling mills for rolling metal sheets. Gerrard. 21154.
Rotary engines. Read. 21271.
Friction clutches. Hopper. 21310.
Fluid pressure governors. Wright. 21342.
Production of gaseous fuel. Southey. 21363.
Tank ships or vessels. Hunter, Black, & De Rusett. 21445.
Discharge valves for ash ejectors. Trewent & Proctor. 21446.
Multi-stage rotary pumps. Parsons & Carnegie. 21490.
Pumps. Pierpont, and Lanston Monotype Corporation, Ltd. 21582.
Variable-speed transmission gearing. Pinson & Blaxley. 22008.
Integrating apparatus for fluid measuring instruments. British Thomson-Houston Company. 22065
Clasp nuts for lathe saddles. Carwardine & Hingston. 22464.
Packing of pistons. Owen. 22692.
Flying machines. Valentine. 22789.
Air-starting and reversing mechanism for internal-combustion engines. Tanner. 22867.
Steam forging presses. Champigneul. 23596.
Steam superheaters for locomotives. Robinson. 24659.
Carburetters for internal-combustion engines. Fagard. 26912.
Starting internal-combustion engines. Clark, Dyke, and Edwards. 27103.
Pneumatic stamps for crushing ore and the like. Holman and Holman. 27273.
Apparatus for burning finely-divided fuel. Babcock & Wilcox, Ltd. 27672, 27673, and 27674.
Apparatus for purifying, cooling, and washing gases. Theisen. 27696.
Device for cutting the webs of double T-girders. Pels. 28068.
Starting devices for internal-combustion engines. Allison and Skinner. 28372.
Bearings. Brown. 28813.
Tap-wrenches of screwing tackle. Shaw & Todd. 29063.
Grinding attachments for lathes. Shaw & Keeling. 29064.
Combustion product engines. Neuberger. 29135.

1912.

Variable-speed gear. Barnett. 2019.
Two-stroke cycle explosion engines. Hardy. 2576.
Gasholders. Blakeley. 3254.
Acetylene gas generators. Marks. 3301.
Drive chains. Belcher. 3505.
Bearings for shafts. Burby. 3617.
Liquid fuel-sprayers for internal-combustion engines. Wedekind. 4352.
Method of and apparatus for the generation of combustion-products under pressure for driving turbines and other fluid-pressure engines. Ainley. 4569.
Combined explosion or internal-combustion and compressed-air engine. Nolet. 4987.
Hydraulic transmission apparatus. Schneider. 5230.
Loose wheels and pulleys. Erlotti. 5965.
Apparatus for indicating speeds at a distance. Siemens Bros. and Co. 6977.
Gas producers. Klusmeyer & Meyer. 7267.
Rotary engines, pumps, and compressors. Champeney. 7535.
Machines for making lock-joined angular metal tubing. Stander. 7593.
Power transmission-devices for motor-driven vehicles. Vorhies. 7887.
Plant comprising an explosion-engine and an engine using products of combustion expansively. Norman & Pape. 8034.
Dampers for steam-generator flues. Crosland & Scholes. 8669.
Governing turbines. Bergmann Elektricitats-Werke Akt.-Ges. 9079.
Steam supply valve with pendulum governor for ships' engines. Brouquiere. 9287.
Flexible shafts. Schurmann. 9394.
Variable-speed gearing. Douglas. 9982.
Ships' construction. Jones. 10405.
Valve-mechanism for internal-combustion engines. Robinson. 10914.
Railway rail joints. Keck. 11349.
Automatic railway couplings. Posszert. 11788.
Self-centring chucks. Stempel. 12136.
Gas-heated crucible furnaces. Fletcher, Russell, & Co., and Fletcher. 12402.
Water-tube boilers and headers therefor. Babcock & Wilcox, Ltd., and Rosenthal. 12431.
Safety valves. Cockburn & MacNicoll. 14053.
Cylinders for double-acting piston engines. Grunwald. 14611.
Lubricating of high-speed internal-combustion engines. F. E. Baker, Ltd., and Wilkes. 14792.
Change-speed gears. Cheneaux. 16083.
Point-changing mechanism for railways. Pestalozza. 16320.
Discharge of coke from vertical gas retorts. Toogood and Robert Dempster & Sons, Ltd. 17616.
Hydraulic transmission apparatus. Schneider. 18894.

ELECTRICAL, 1911.

Production of periodically-varying currents of high frequency. Weintraub. 14504.
Electrical switches. Cox. 21037.
Power and electrical installation of power-propelled vehicles. Lanchester. 21322.
Dynamos. Parsons & Law. 21496.
Automatic electric switching apparatus. Howard & Allen. 21649.
Means of enclosing electrical apparatus. Curtis, and Adams Manufacturing Company. 22372.
Calling apparatus for telephones. Wall. 23122.
Electric furnace. Mettler. 25890.
Type-printing telegraph apparatus. Aktieselkabet Hovlands Radiotelegraf. 26039.

1912.

Electric lifts of the alternating type. Moysey. 3144.
Means of making contact or operating electric signals for use principally in mines. Fryar. 5919.
Electric time switches. Schmid. 6078.
Apparatus for the generation of electricity from the motion or currents of water. Visser, De Goede, & De Veen. 6962.
Anode supports for use in electro-plating. Spirella Company of Great Britain. 9148.
Telephone receivers. Parr. 10616.
Alternating-current distribution systems. Sprong & McCoy. 12682.
Earthing arrangements for electrical systems. Siemens Schuckert-werke. 12738.
Arc lamps. Moul. 14516.
Electrical junction boxes. Murray. 19534.

METAL QUOTATIONS.

TUESDAY, OCTOBER 15TH.

Aluminium ingot	82/- per cwt.
„ wire, according to sizes, &c. ......from	102/- „
„ sheets „ „ ...... „	120/- „
Antimony ......£36/-/- to	£38/-/- per ton.
Brass, rolled	$9\frac{1}{8}$d. per lb.
„ tubes (brazed)	$11\frac{3}{4}$d.
„ „ (solid drawn)	10d.
„ „ wire	$9\frac{1}{8}$d.
Copper, Standard	£75/5/- per ton.
Iron, Cleveland	$65/7\frac{1}{2}$ „
„ Scotch	$71/7\frac{1}{2}$ „
Lead, English	£21/15/- „
„ Foreign (soft)	£21/7/6 „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£8/-/- per bottle
Silver	$29\frac{5}{16}$d. per oz.
Spelter	£27/12/6 per ton.
Tin, block	£223/10/- „
Tin plates	$15/7\frac{1}{2}$ „
Zinc sheets (Silesian)	£31/5/- „
„ (Stettin; Vieille Montagne)	£31/10/- „



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The Inspection of Steam Pipes.

THE beneficent action of the Boiler Explosions Act by the searching character of its Board of Trade enquiries and the publication of their judgments has succeeded in preventing to a large extent the occurrence of serious boiler explosions. It is true the number of enquiries annually held has not been greatly diminished, but these are concerned mainly with minor failures of auxiliary apparatus used for steaming and heating purposes not attended with disastrous consequences, and many of them differ little from what are usually ranked as the ordinary incidents of wear and tear, but it is well to remember in this connection that when steam at high pressure is suddenly liberated into a confined space there is always serious risk of serious or fatal scalding where workpeople are present, and for this reason we have consistently advocated the thorough periodical inspection of all auxiliary steaming apparatus and their connections, and particularly steam pipes. They constitute a sphere of somewhat ill-defined responsibility. When contracts are entered into with engine or boiler makers the work usually ends at the engine or boiler stop valve. The connections are left for subsequent consideration, and if they are not carefully thought out like other parts of a power scheme, there is a risk of their being badly arranged, imperfectly drained, or constructed of cast iron instead of steel, and lastly, to make matters worse, they are often excluded from the periodical inspection which main boilers and large steaming vessels usually receive, their small diameter and large margins of strength leading many owners and users to regard this as a work of supererogation and unnecessary expense. The judgment of a Board of Trade enquiry held at Manchester during the past week into the circumstances attending a fatal steam pipe explosion at the Dan Lane Mill of the Fine Cotton Spinners' Association

at Atherton on September 21st, 1911, should do something to dispel this delusion. The disaster itself strikingly illustrates not only how terribly fatal a steam pipe failure may prove, but also the way such failures are often brought about and how easily they may be avoided. As a result of the rush of steam which took place, no fewer than six persons lost their lives, while three others were badly scalded. The pipe itself was of cast iron and an inspection of its broken fragments revealed the existence of a defect to which cast-iron pipes are particularly prone unless great care is exercised in their manufacture. Instead of having a uniform thickness of between ⅝in. and $\frac{11}{16}$in., it was, owing to the shifting of the core during the moulding operations, very uneven along a longitudinal line and at one spot was little more than $\frac{1}{16}$in. thick. The pipe was made originally when the engines worked at 120lbs. on the inch, and subsequently, when a new boiler was installed at a pressure of 160lbs. some 10 years ago, it was inserted into the connections that were then made. That it should have withstood the working conditions so long shows how large the *nominal* margin of safety was and also how the stresses and fatigue to which the pipe was subjected eventually found the weak spot. We have italicised the word "nominal," since it is important to recognise that the expansions and contractions to which steam ranges are subjected impose stresses upon them which cannot well be estimated, but which are often severe and therefore demand a large factor of safety. We also take this opportunity of pointing out that for such high pressures as those indicated cast iron is quite unsuitable. In the course of the enquiry a dispute arose as to whether the responsibility for the weak pipe rested with the engineer to the Fine Cotton Spinners' Association or with Messrs. Musgrave, who made the alterations in 1902. Into this we need not enter. It is sufficient to say that the Board of Trade Commissioners, in giving judgment, expressed the opinion that Messrs. Musgrave would never have erected a composite range of steam pipes unless they received special instructions from the persons employing them, and that such instructions in some form or other must have come from the millowners at the time, while a factor of greater importance was that no steps were taken to submit the pipes to periodical inspection, although in three years after they were installed they were subjected to a considerable increase in pressure. This continued lack of precaution on the owners' part led the Commissioners finally to utter a warning which it is to be hoped all other steam users will lay to heart. The court, they said, "are sorry to hear that, even after the serious consequences which followed the explosion, the owners have not thought fit to insure those pipes, and we desire to say that if pipes charged with high-pressure steam are not properly inspected from time to time, we shall have to take some steps in future enquiries to make such order for costs as will bring the owners of steam pipes to take proper precautions for their safe working." After this utterance, it will be impossible for millowners to plead that they did not consider insurance or inspection of steam pipes necessary, or to evade the consequences which neglect to do so will in all probability entail.

INSTITUTE OF MARINE ENGINEERS.

MR. SUMMERS HUNTER delivered his presidential address at a meeting of the Institute of Marine Engineers held on Monday, October 14th, afterwards presenting the Denny Gold Medal awarded to Mr. John McLaren (Member) for his paper on "Wireless Telegraphy," read December 11th, 1911. In the course of his address Mr. Hunter referred to the slow developments in the early stages of steam power; to the more recent progress of naval architecture and marine propulsion; and to the successful development of the internal-combustion engine; the application of the gas producer and gas engine to marine work, and to the later system of electrical propulsion of ships, early attention to which had been directed through the Institute, and to all the other aids to progress and economy. The success of the turbine, directly applied to fast vessels, he said, had led to its adoption for the merchant steamer, where it could be successfully used in combination with the reciprocating engine or with gearing. With the latter method he was particularly impressed. The reliability of mechanical gearing had been demonstrated and its use was likely to become more general. Superheating was to-day engaging considerable attention. There were now some 700 vessels of various types fitted with superheaters, about 600 of which were owned on the Continent and were nearly all fitted with the Schmidt type of superheater. On the Continent, a passenger liner about 800ft. long and of 30,000 i.h.p. was being built and would be fitted with these superheaters. This vessel would have twin-screw triple-expansion engines and the consumption of coal, it was estimated, would be from 10 to 15 per cent. less than with saturated steam. This saving could be effected in almost any triple-expansion engine, and with perfect safety. An interesting feature of this system was that it could be applied to almost any existing marine reciprocating engine without structural alterations. This was an important consideration for shipowners, who were somewhat concerned as to what to do with their steam-driven boats when competition with oil engines and other motors became more acute.

The development of the oil engine had been so rapid that already there were as many, or possibly more, varieties of the oil engine than of the steam engine. On inland waters and for short coastal voyages there were now some hundreds of oil-driven vessels at work, chiefly of low power and slow speed. Of ocean-going vessels there were at present about six of 3,000 tons up to 6,000 tons deadweight at sea, four of which had engines on the 4-stroke system, and the rest on the 2-stroke; but he believed there were at least 27 or 28 under construction, of which 17 had 4-stroke engines; nine had 2-stroke single-acting and two or three had 2-stroke double-acting, the size of the vessels varying from 2,000 to 15,000 tons. Each of these types had its advantages under different conditions. Much had been written and said about the motor or gas-driven warship, but as yet little had been done beyond realising the advantage of a deck free from funnels and easily protected from attack by air-craft. Before long we might see warships of all sizes specially designed for local waters, leaving the long-voyage or ocean-going warship to be something of a different design altogether. He hoped this country would not lag behind. If these special vessels were to be oil-driven (as was more than likely) then we should be up and doing. If it was possible to produce a warship with a clear deck it would be a superior fighting machine and, such being the case, the warship and the merchant ship were on an entirely different basis so far as the cost of oil was concerned.

After commenting upon the improvements effected in methods of manufacture and foundry practice, Mr. Hunter dealt with the question of the education and training of the engineers of the future, and in this connection said he was very strongly of the opinion that lads who could take advantage of the best possible training should have at least a year in the shops immediately after leaving school. Afterwards their time should be divided between technical colleges and the works. Ordinary apprentices could take advantage of the system also by qualifying at evening classes. In commenting upon the work of the Institute, Mr. Hunter referred to the scheme for the acquisition of premises in the City and commended it to all connected with the shipping industry for support. He also remarked upon the efforts being made to provide a suitable memorial to the engineers of the "Titanic" as a permanent record of their devotion to duty. A vote of thanks was heartily accorded to Mr. Hunter, on the proposal of Mr. J. T. Milton (Chairman of Council), seconded by Mr. John McLaren.

Traction Engine Boiler Explosion in a London Street.—The boiler of a steam traction engine exploded in Queen Street, Hammersmith, on the 16th inst. The driver, who was seriously injured, was removed in an unconscious condition to the hospital, but two other men who were thrown from the engine escaped unhurt.

TESTS OF A 1,000 H.P. BABCOCK & WILCOX BOILER.*

BY B. N. BUMP.

THE boiler tested was erected as an experiment for the purpose of determining, by test and by continuous operation in the regular service of a large plant, the advantages and disadvantages of so high a boiler (24 tubes high) of the Babcock and Wilcox type. These tests were made from November, 1911, to February, 1912. They were expected to answer the following questions: (*a*) At what rating will the highest efficiency be obtained? (*b*) Will the superheat obtained with the superheater located above the 24th tube be sufficient to pay for the installation of the superheater? (*c*) Will the last pass of the boiler be effective? (*d*) Can the exit gas temperature be reduced very nearly to the temperature of the steam in the boiler? (*e*) If the exit gas temperatures are close to the steam temperature, will pitting occur in the back end of the boiler due to the sulphur content of the gas?

their exit between the downtakes, and through the rear wall to the stack. The spaces between the header, both front and rear, were packed with asbestos.

The boiler is fired by a 6-retort Taylor stoker, grate area 62·465 sq. ft., not including any dump grate area. The ratio of boiler heating surface to grate area is 160 to 1. The ratio of boiler plus superheater surface to grate area is 188 to 1. The height of the combustion chamber is about 6·5ft., and the width of the furnace 12ft. 7in., which latter is greater than the width of the stoker to allow for placing a cast-iron wind-box on either side of the stoker. This is believed to be a new feature, tried as an experiment. Previously there had been trouble from the formation of clinker on the side walls with stokers of both the underfeed and overfeed type, owing to some coals giving a tough sticky clinker which is very troublesome. With the side walls against the stoker, clinker forms rapidly, and is difficult to remove. Setting back the side walls lessens clinker formation to some extent, and facilitates the removal of the clinker.

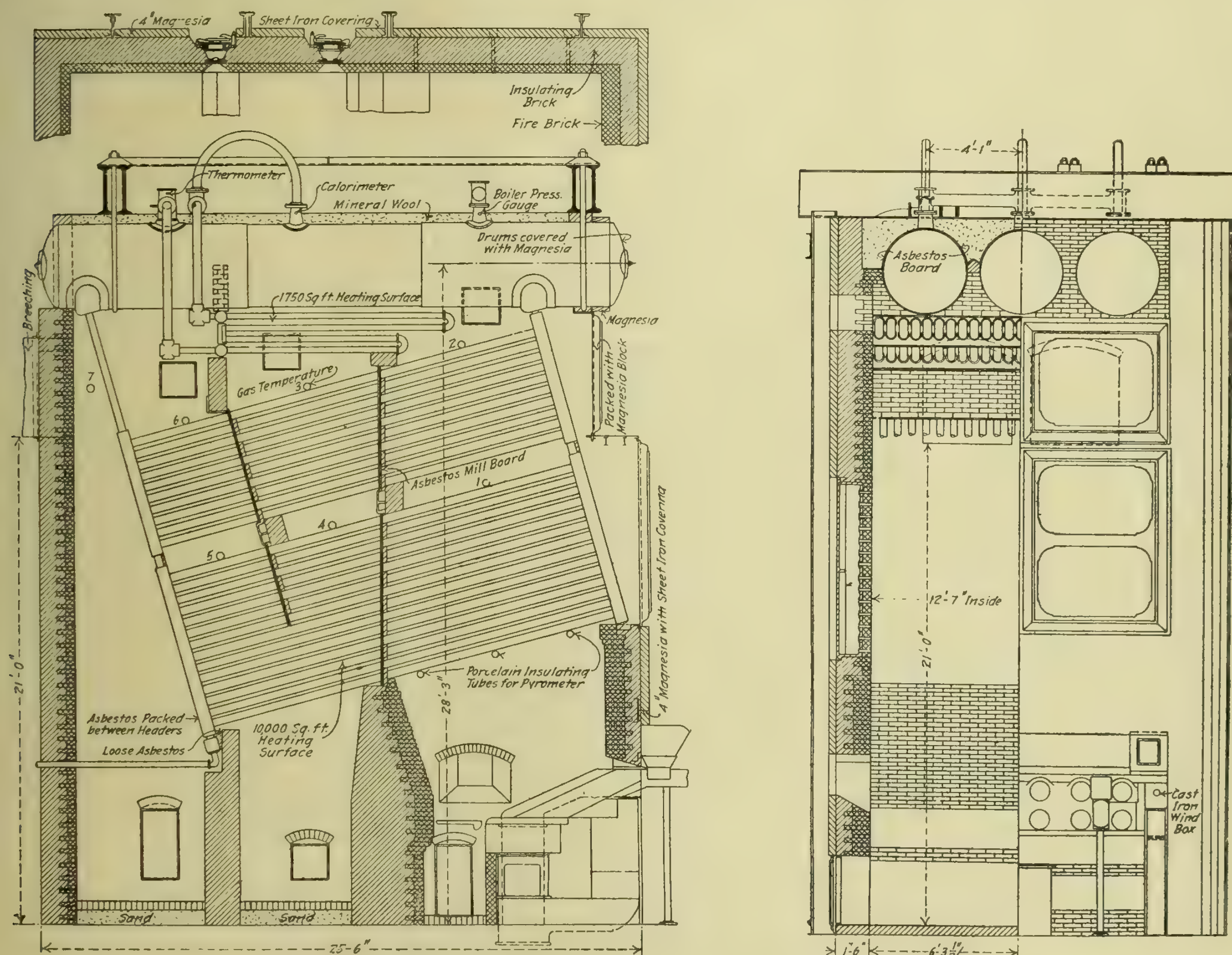


FIG. 1.—LONGITUDINAL SECTION AND FRONT ELEVATION OF BABCOCK & WILCOX BOILER.

The boiler was built up of one regular 14-tube section, and above this, with a space of some 11in. between them, was placed a 10-tube section. The headers of the 10-tube and 14-tube sections were joined by short nipples, making a 24 high header. There are 21 of these sections, containing a total of 504 tubes. The tubes are 4in. diam. and 18ft. long. There are three drums 42in. diam. and 24ft. long. The water-heating surface of the boiler is 10,000 sq. ft. Between the top tubes and the drums a Foster superheater is placed containing 1,750 sq. ft. of superheating surface.

The gases make three passes through the boiler. The baffles are arranged to give a gradual decrease in space through the first and second passes in the direction of flow, which tends to maintain the velocity of the gases as the temperature decreases. The gases enter the superheater from the top of the first pass, after travelling over 24 tubes. From the superheater they turn downward through the second pass; upward through the third pass, and then make

A brick ledge between the stoker and side wall is objectionable, because in time clinker will fasten to it and it is almost impossible to get a bar between clinker and ledge. The cast-iron wind-boxes overcome the objections to the brick ledge by chilling the clinker so that it does not stick. A bar can always be forced between the clinker and wind-box to raise the clinker. A part or all of the air from the blast fan is passed through these wind-boxes on its way into the stoker. After six months of continuous service there is no sign of burning on the wind-boxes.

Fig. 1 shows a front and side elevation of the unit. On the side elevation the locations of the pyrometer rods and gas sampling tubes are shown. The furnace temperatures were taken through the three openings shown just under the lower tubes. The other gas temperatures were taken at positions 1 to 7 inclusive. The numbers on the data sheets and charts of gas temperatures refer to these positions.

The walls were lined with 9in. of firebrick backed up by 9in. of porous insulating brick. The outer surfaces of all

* Abstract of paper read before the American Society of Mechanical Engineers.

walls were painted with two coats of boiler pitch to prevent any filtration of air through the brickwork. Against these painted surfaces of the front and side walls 85 per cent. magnesia covering 4in. thick was placed. The magnesia was held against the brick and protected by a thin steel shell. Asbestos board was placed on the top half of the drums, then loose mineral wool was placed over the entire top of the boiler.

The tests varied from 18 to 48 hours in length, although most of them were about 24 hours long. The boiler was examined for leaks at frequent intervals, and the boiler tubes were dusted every 48 hours in the intervals between tests. It was found necessary to have some suction over the fire to prevent the escape of gas into the boiler-room. This suction was kept as low as possible.

The first 19 tests were made with mixed coal, from four different mines all in the same region. Tests Nos. 21 to 40 were all run on coal from No. 29 mine, lighter than that used on the early tests and giving much less clinker trouble. It made a loose fuel bed and allowed more boiler capacity with less draught in the stoker. For best combined efficiency the dry coal per square foot of grate per hour is about 26lbs., or nearly 270lbs. per retort. The quantity of coal burned per square foot of grate per hour was increased to nearly 63lbs., with a decrease in combined efficiency of 5·5 per cent.

The radiation and unaccounted-for losses have been calculated for those tests, for which there were ultimate analyses of the coal. The tests were made during extremely cold weather, and there was over the boiler only a temporary building affording but little protection from the elements; the boiler-room temperatures were so low at times the boiler pressure gauge piping and the water column blow-off piping froze. In view of these facts and the draughty condition of the boiler-room the radiation and unaccounted-for losses of from 5 to 7 per cent. are worthy of note.

The theoretical efficiency was calculated on the assumption that the only heat loss was that to the stack when the combustion was complete without excess air, and the temperature of gas leaving the boiler was equal to the temperature of the wet steam in the boiler. The efficiencies in Table I. have been calculated for those tests for which there were ultimate analyses of the coal.

It may be possible, under favourable conditions, to reduce the radiation losses to 2·5 per cent. With thorough mixing and a suitable type of combustion chamber the heat losses in the gas may be expected to be not more than 1·5 per cent. greater than the theoretical gas loss; the maximum combined efficiency which may be attained under these most favourable conditions is about 85 per cent.

TABLE I.—*Theoretical Efficiencies.*

No. of Tests.	Theoretical Efficiency per cent.	Combined Efficiency per cent.	Gain in Efficiency necessary to attain Theoretical Efficiency.
8	90·10	79·60	10·50
11	90·15	78·14	12·01
16	90·05	76·18	13·87
18	89·95	75·20	14·75
25	89·52	75·79	13·73
35	89·90	78·33	11·57
39	89·85	78·65	11·20

The best combined efficiencies are obtained with 56 to 66 per cent. of the boiler rating. The efficiencies fall off slowly as the quantity of steam generated is increased. The extreme variation in efficiency shown by the individual tests is from 75·2 to 81·3 per cent.

The gain in efficiency due to the superheater seems to bear no definite relation to the amount of moisture in the steam entering the superheater. By gain in efficiency due to superheater is meant the heat absorbed by the superheater in percentage of the total heat in the coal. The superheat shows a general tendency upward with the increase in boiler rating. For 60 per cent. of the boiler rating the superheat is about 36° Fah., and for 120 per cent. rating about 74° Fah. At 60 per cent. rating the weight of steam passing through the superheat is 18,000lbs. per hour, the amount for which the superheater was built. The pressure drop through the superheater for its rated quantity of steam is 5lbs.; at 120 per cent. boiler rating the weight of steam passing through the superheater is double that for which the superheater was designed, and the pressure drop through superheater is 28lbs.

At the low boiler ratings the last pass of the boiler, and in fact the last two passes, are of very little use. The best combined efficiencies were obtained when running between 56 and 66 per cent. of boiler rating. At these low ratings the drop in gas temperature through the second and third passes altogether is about 20° Fah., and the heat absorbed is very small, about 1·3 per cent. of the total. These two passes have 50 per cent. of the boiler heating surface. If the second and third passes were dropped off entirely, the loss in combined efficiency would be about 1 per cent. at the low rating. It is only when the boiler has reached 75 per cent. rating or more that the gain in economy in the last two passes is sufficient to give a reasonable return upon the investment in heating surface. While the exit gas temperatures were reduced almost to the lowest theoretical limit which can be reached without the use of an economiser, it was done at a large expenditure in heating surface.

When running at about 50 per cent. of boiler rating the temperature of the gases leaving the boiler is practically that of the steam in the boiler. As the capacity is increased the difference between the temperature of the gases leaving the boiler and the temperature of the steam in the boiler increases. The increase in the difference between these two temperatures seems to be approximately in the same ratio as the increase in capacity, so that for an increase from 50 to 100 per cent. of the boiler rating the difference in temperature between exit gases and steam increases about 50° Fah.

An examination of the boiler after more than six months' service showed no evidence of pitting of the heating surface of the last pass due to the sulphur content of the coal and low exit gas temperature.

TABLE II.—1,000 *H.P. Boiler, Résumé of Principal Results.*

Test No.	Per Cent. Rating	Combined Efficiency.	Temperature of Gases leaving Boiler, Deg. Fah.	CO_2 in Gases leaving Boiler, Per Cent.	Per Cent. Combustible in Dry Refuse.	B.T.U. per Lb. Dry Coal.	Evaporation from and at 212° Fah. per lb. Dry Coal Combined Unit.	Quality of steam leaving Boiler.	Radiation and Unaccounted for Losses.
1	84·79	78·02	390	10·32	15·49	14334	11·525	97·92	—
3	56·72	80·89	363	—	10·30	14541	12·121	97·83	—
4	61·77	77·93	368	10·10	10·09	14517	11·658	97·93	—
5	59·48	79·10	361	9·39	13·91	14498	11·818	97·99	—
6	61·43	80·76	368	9·00	8·64	14499	12·067	98·16	—
7	60·87	81·00	367	9·00	1·44	14526	12·125	98·20	—
8	60·60	79·60	367	10·38	3·90	14493	11·889	98·11	5·46
9	57·36	77·71	364	10·16	3·39	14445	11·567	98·00	—
10	55·88	81·30	362	10·02	9·69	14289	11·972	97·97	—
11	67·94	78·14	369	10·30	10·93	14624	11·775	97·94	6·42
12	66·43	80·69	373	11·20	17·91	14454	12·018	98·11	—
13	68·86	78·89	375	10·50	18·08	14396	11·704	98·01	—
14	74·25	78·64	381	10·59	14·75	14602	11·833	98·23	—
15	84·94	76·88	390	10·44	23·79	14467	11·461	98·15	—
16	76·21	76·18	383	10·54	23·52	14590	11·453	98·14	6·99
17	76·77	78·76	383	10·68	21·10	14618	11·864	98·20	—
18	89·08	75·20	401	10·22	20·05	14645	11·349	98·00	7·15
19	90·75	75·42	396	10·77	24·50	14471	11·247	98·01	—
21	108·83	76·21	412	10·75	28·73	14518	11·401	98·03	—
22	106·90	75·50	415	10·89	21·48	14462	11·252	98·02	—
23	93·93	76·18	399	10·15	17·80	14263	11·197	97·84	—
24	107·66	76·87	412	10·00	25·76	14522	11·504	98·00	—
25	127·70	75·79	423	11·66	30·68	14415	11·258	97·99	5·65
26	121·36	75·93	426	11·35	29·18	14290	11·181	98·42	—
27	75·65	77·28	379	10·17	14·94	14284	11·375	98·05	—
29	71·63	78·76	367	10·01	14·37	14254	11·569	98·10	—
30	73·75	77·49	369	9·84	16·23	14430	11·523	98·11	—
33	77·80	76·48	376	9·24	20·14	14380	11·333	98·09	—
34	67·53	78·77	374	9·31	7·99	14376	11·670	98·05	—
35	63·05	78·33	376	9·39	7·07	14455	11·668	98·04	5·00
37	62·46	79·08	369	9·42	7·59	14409	11·742	98·10	—
39	53·98	78·65	360	8·84	4·69	14515	11·764	97·80	4·75
40	53·72	78·79	360	9·43	5·09	14378	11·675	97·93	—

Tests 1–19 inclusive with mixed coal from mines Nos. 24, 25, 27 and 29
Tests 21–40 inclusive with coal from No. 29 mine only.

DROP FEED LUBRICATOR.

We illustrate herewith a patented design of drop feed lubricator provided with automatic means for closing a siphon system attached eccentrically to a float, which has recently been placed on the market by the Stern Sonneborn Oil Company, Ltd., Royal London House, Finsbury Square, London. In the present drop feed lubricators which have been provided with a float-carried siphon, and in which it has been proposed to employ an adjustable needle valve in the delivery arm of the siphon, it has been found necessary, when the oil has run out of the reservoir, to separately fill up and adjust the siphon attached to the float when refilling the lubricator. In the design under notice this latter disadvantage is entirely obviated, and for this reason enables the feed of the oil feed to be regulated once and for all.

Fig. 1 is a vertical section of the lubricator, Fig. 2 is a vertical section showing the device in position when the oil has been exhausted from the reservoir and the siphon closed, and Fig. 3 is a similar view with the reservoir filled and the siphon unclosing. The float 3, guided by the tube 2, floats upon the oil in the oil reservoir 1, see Fig. 1, and to the float is eccentrically attached a siphon consisting of the suction tube 4 and the fall tube 5. When both the suction and fall tubes 4, 5, are filled with oil, a uniform feed of oil takes place which is independent of the level of the oil in the reservoir 1, in consequence of the difference of the heights H_1 H_2 and h according to the formula: $H_2 - (H_1 - h) = H$ where H = the height of fall of the oil.

Fig. 1.—Drop Feed Lubricator.

When the oil has run out of the reservoir 1, an automatic shutting-off action takes place. The end 6 of the suction tube 4, which is bell-mouthed (see Fig. 2), moves down against a plate 7 (or against the base of the reservoir, which is smoothly ground in order to secure a tight joint), and closes the suction tube of the siphon hermetically. The weight of the float 3 with the siphon, only closes the reservoir when the centre of gravity of the system lies within the supporting surface of the mouth 6, as can be seen in Fig. 2. It is for this reason that the siphon system is arranged eccentrically.

In consequence of the hermetic closure made by the mouth 6 with the base or plate 7, the oil contained in the siphon cannot run out. Equilibrium is set up in the siphon and the feed or delivery of the oil is interrupted. The equilibrium is destroyed when the reservoir is refilled with oil. When the float is covered with oil, as shown in Fig. 3, its upward thrust indicated by the arrow A acts in opposition to the weight of the system indicated by the arrow G. In consequence of the difference of the points of application of these two forces, a couple of forces is produced which when calculated from the supporting point gives $A \cdot b - G \cdot a = M$ when M is equal to the moment of the couple of forces.

The moment of the couple of forces interrupts the hermetic closure. Interruption of the hermetical closure can only be produced by a tilting moment, as the suctional forces, which are produced when ground parts are employed, are very strong. A tilting moment is, however, only attained by the eccentric arrangement of the siphon system employed. When the hermetical closure is destroyed the float rises and floats on the oil contained in the reservoir. The siphon system immediately again commences its activity automatically, because during the interruption it remains full permanently and delivers the quantity of oil adjusted once for all at the point of consumption. The oil outlet of the siphon is regulated by a screw-governed needle valve 8, as shown at Fig. 1, in which the oil passes through a stop cock 9 and drops through an

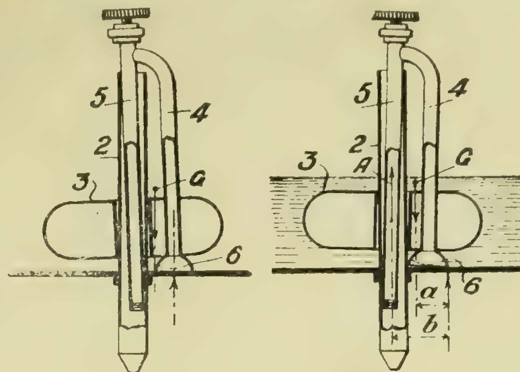


Fig. 2. Fig. 3.
Drop Feed Lubricator.

inspection glass 10. When the oil again runs out of the filled reservoir, closure again takes place and the above-described operations are again repeated.

THE RELATION OF THE "HORSE-POWER" TO THE "KILOWATT."*

There was before 1911 no precise definition of the horse-power that was generally accepted and authoritative, and different equivalents of this unit in watts are given by various books. The most frequently used equivalent in watts, both in the United States and England, has been the round number, 746 watts; and in 1911 the American Institute of Electrical Engineers adopted this as the exact value of the horse-power. It is obviously desirable that a unit of power should not vary from place to place, and the horse-power thus defined as a fixed number of watts does indeed represent the same rate of work at all places. Inasmuch as the "pound" weight, as a unit of force, varies in value as g the acceleration of gravity varies, the number of foot-pounds per second in a horse-power accordingly varies with the latitude and altitude. It is equal to 550 foot-pounds per second at 50° latitude and sea level, approximately the location of London, where the original experiments were made by James Watt to determine the magnitude of the horse-power.

The "continental horse-power," which is used on the Continent of Europe, differs from the English and American horse-power by more than 1 per cent., its usual equivalent in watts being 736. This difference is historically due to the confusion existing in weights and measures about 100 years ago. After the metric system had come into use in Europe, the various values of the horse-power in terms of local feet and pounds were reduced to metric units and were rounded off to 75 kilogram-metres per second, although the original English value was equivalent to 76·041 kilogram-metres per second. Since a unit of power should represent the same rate of work at all places, the "continental horse-power" is best defined as 736 watts; this is equivalent to 75 kilogram-metres per second at latitude 52° 30′, or Berlin. The circular gives tables showing the variation with latitude and altitude of the number of foot-pounds per second and of kilogram-metres per second in the two different horse-powers.

These values, 746 and 736 watts, were adopted as early as 1873 by a committee of the British Association for the Advancement of Science. The value, 0·746 kw., will be used in future publications of the Bureau of Standards as the exact equivalent of the English and American horse-power. It is recognised, however, that modern engineering practice is constantly tending away from the horse-power and toward the kilowatt. The Bureau of Standards and the Standards Committee of the American Institute of Electrical Engineers recommend the kilowatt for use generally instead of the horse-power as the unit of power.

* Abstract, Circular of the U.S. Bureau of Standards, No. 34; June 1, 1911.

HEAVY OIL ENGINES.*

BY CAPT. H. RIALL SANKEY, R.E. (RETIRED), M.INST.C.E.

(*Continued from page 478.*)

Essential Elements of a Diesel Engine.—It will thus be seen that the Diesel engine can work either as a four-stroke or as a two-stroke engine. In the four-stroke engine the following are the essential elements, illustrated diagrammatically in Fig. 9: (1) A cylinder, in which works a piston connected in the usual way to a crank shaft. This cylinder, surrounded by a water jacket to keep it cool, is fitted with—*a*, an air valve; *b*, a fuel valve; *c*, an exhaust valve. All these valves are opened by a two-to-one shaft, driven by the engine, and generally closed by means of springs. (2) A fuel pump regulated by the governor. (3) An air compressor to provide high-pressure air for pulverising and injecting the fuel.

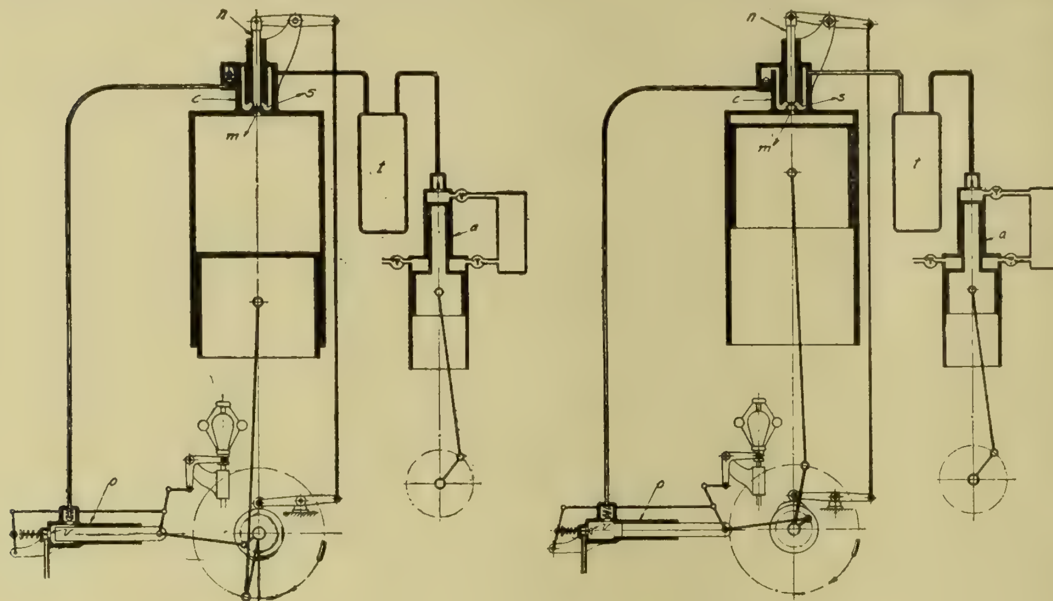


Fig. 9.

In the case of the two-stroke Diesel engine, the essential elements are the same as those given above. The two-to-one shaft, however, runs at the same speed as the crank shaft of the engine, and a low-pressure air compressor or blower has to be added for supplying the scavenging blast of air.

The cycle of operations of the two types of engines can also be laid out on a time base, as shown in Fig. 10. In this figure it is assumed that each stroke occupies one-sixth of a second, that is to say, the engine is running at 180 revs. per minute. It will be observed that in the four-stroke cycle the exhaust pressure is slightly above and the air-suction pressure slightly below atmosphere. In the two-stroke cycle there is very little time for the exhaust and scavenge, and obviously the turning effort is far better than in the four-stroke cycle.

Design of Diesel Engines.—As already stated, the essential part of the Diesel engine is the fuel valve, and it requires special design; the other valves are like those adopted for gas engines, and the method of driving them is substantially similar. All the other parts, a list of which will be given later, are similar to the corresponding parts of a steam or of a gas engine, and in a general way their design follows that adopted for those engines. The differences are mainly those of dimensions, brought about by the far greater pressures that have to be withstood. As regards the cylinder, in the case of a steam engine the high-pressure cylinders have to be designed for working pressure of from 150lbs. to 200lbs. per square inch, whereas, both in gas and Diesel engines, working pressures of at least 500lbs. per square inch have to be considered.

The dimensions of connecting rods and crank shafts depend on the maximum forces applied to them, and not on the average forces, and both in gas and Diesel engines the ratio of the maximum to the mean force is far greater than in the case of the steam engine; this leads to greater scantlings. Occasionally, however, the parts of all these engines may have to withstand much higher stresses, due, in the case of the steam engine to water-hammer, in the case of the gas engine to pre-ignition, and in the case of the Diesel engine to a charge remaining in the cylinder unignited and causing an explosion at the top of the next stroke, thus increasing the pressure to about 1,700lbs. per square inch. So long, however, as the stress thus produced is sensibly below the elastic limit of the material no harm will be done.

It will be gathered from the above that the thickness of cylinder walls, the strength of cylinder covers, studs for securing the cylinder covers to the cylinders, the framework generally, the connecting rods, and the crank shaft, will be much greater in the case of the Diesel oil engine than in a steam engine of equal power running at the same speed. These increased scantlings of the Diesel engine produce a feature which immediately attracts attention.

Apart from the power to be developed, the design and dimensions depend also on the type of Diesel engine under consideration, and these may be classified as follows:—

Slow speed, 100 revs. to 200 revs. per minute.

High speed, 300 revs. to 600 revs. per minute.

Vertical or horizontal.

Four-stroke, single acting or double acting.

Two-stroke, single acting or double acting.

One, two, three, or more lines (an eight-line engine has already been constructed).

The large number of different designs that can be produced by combining two or more of these various types is obviously very great, and at present the process of selection is going on. There would not be time to go seriatim through all these various types, but a few of them will be described in a general way. A good idea of the general design can be obtained by studying the more usual arrangement adopted for a single line, vertical, four-stroke, slow-speed Diesel engine of 100 b.h.p., of the kind now being manufactured by a very large number of firms in this and other countries.

In this design the engine is single-acting, and the piston is of the variety known as a trunk piston, which also acts as a guide, so that no piston rod or cross-head guide is required, and the cylinder can be placed much nearer to the crank shaft, thus reducing the height of the engine materially. The

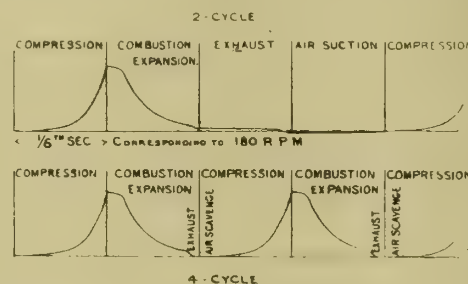


Fig. 10.

vertical section of such an engine is given in Figs. 11, 12, and 13, and the various important parts are as follows: (1) The base; (2) Bearings; (3) Lubricating pump; (4) Crank shaft; (5) Flywheel; (6) Framing; (7) Connecting rod and its bearings; (8) Trunk piston; (9) Piston rings; (10) Cylinder and jacket; (11) Cylinder cover; (12) Two-to-one shaft; (13) Levers for actuating valves; (14) Special air valve levers for starting; (15) Fuel valve; (16) Exhaust valve; (17) Air suction valve and pipe; (18) Air compressor; (19) Compressed-air vessels; (20) Fuel pump; (21) Fuel tank; (22) Governor and its drive; (23) Exhaust pipe and silencer.

Each of these parts will now be considered in the order

* Howard lectures delivered before the Royal Society of Arts, April-May, 1912. Reproduced from the "Journal of the Royal Society of Arts."

named, and at the same time some of the modifications that are made by various constructors will be described.

In the design shown in Figs. 12 and 13, the walls of the jacket cylinder form part of the framework of the engine, thus connecting the cylinder cover through the A frame to the base and making a fixed link in the kinematic chain, known as a slider crank chain, to which all such reciprocating

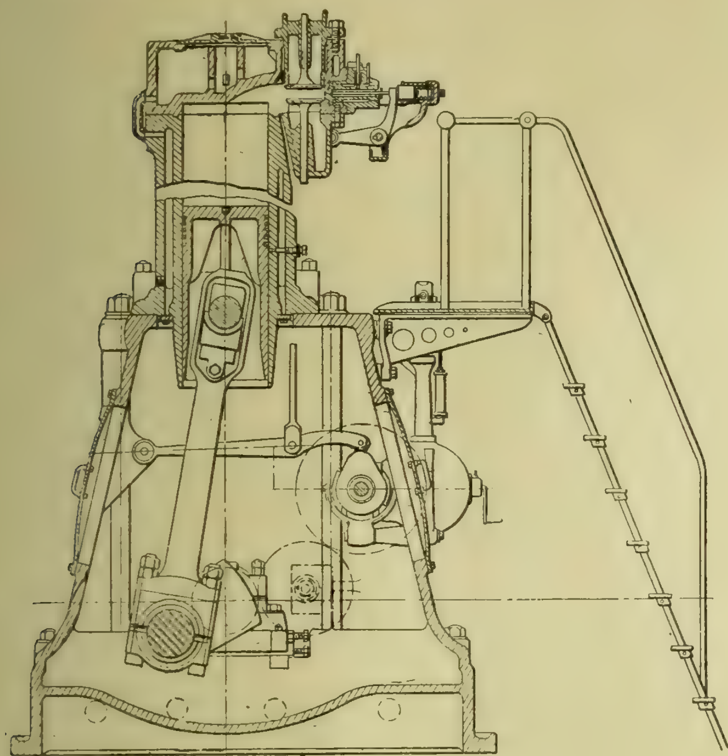


FIG. 11.

engines belong. In Fig. 11 the jacket cylinder is bolted to the A frame, or rather to the crank chamber. The former is the more usual design for slow-speed engines, and is adopted by Sulzer, Willans & Robinson, Burmeister, and Wain, and many other builders, even for large engines; and in this case the engine is not enclosed, the A frame itself forming the necessary shield to prevent the splash of the lubricating oil. There does not seem to be any special reason for adopting a closed crank chamber in the case of low-speed engines, and the open frame has many advantages, such as easier inspection whilst running, greater ease in getting at parts for repairs, and greater ease for the heat to radiate, thus keeping the bearings cooler. In the cases referred to above, the cylinder proper is formed as a liner, and can be removed by taking off the cylinder cover and without dismantling the engine. In some cases the cylinder and liner are formed in one casting, bolted to the A frame or to the crank chamber, as, for example, in the marine engines made by the Maschinenfabrik Augsburg-Nürnberg Company.

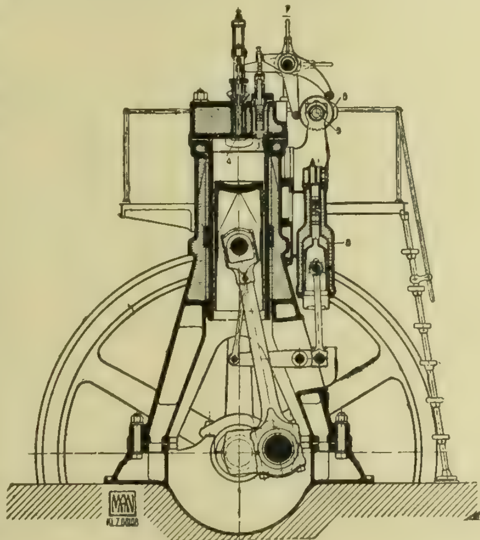


FIG. 12.

1. *The Base.*—This is in the form of a box-casting, with holes through it for bolting to the foundations. There are facings machined to take the flanges of the A frame or crank chamber, and seatings are machined for the bearings. In engines of 1,000 h.p. and upwards, Messrs. Krupp, Sulzer, and Carels, make the base in segments, bolted together *in situ*.

2. *Bearings.*—The bearings for the crank shaft are usually of white metal in cast-iron or steel shells. The white metal is continuous over the whole bearings, and the shell must be carefully tinned so as to obtain good metallic contact between the white metal and the shell, in order to reduce the heat resistance which would otherwise exist between the surfaces of the two metals, so as to conduct away the heat which is produced by the friction of the bearings.

3. *Lubricating Pump.*—When forced lubrication is used, which is the arrangement adopted with closed crank chambers, practically any type of forced lubrication pump will do. The various makers have their own design on which they rely. The oil pipes connecting the lubricating pump to the various bearings are usually made of copper. The oil flows back into the base, and after being strained return to the pump. Some makers have an independent pump for lubricating cylinders, in which case the oil is forced through small holes at the base of the liner at the end of the working stroke. The bearings at both the big and small end of the connecting rod are forced lubricated, but in small and medium engines the crank-shaft bearings are lubricated by means of a ring. In large engines these bearings are also forced lubricated.

4. *Crank Shaft.*—Forged nickel steel is used by many makers. As already pointed out, the crank shaft of the Diesel engine is subject to greater inequality of torque than that of the steam engine; it is also subject to heavy shearing stresses, and in the case of single-acting engines to reversal of stress. Thus much larger diameters are required, in the same way as was found to be necessary in the case of the Willans' engine, and the effect may be gathered from the following. A shaft transmitting 100 h.p. at 200 revs. per minute by pure torque, *i.e.*, when there is no bending stress, should be 2·6 in diameter; but when exposed to the maximum bending stresses likely to occur in practice, the diameter must be increased to 4in., and the latter may be taken as the conditions of working for an ordinary steam-engine crank shaft. To meet the requirements of the Diesel engine, as stated above, the diameter of the shaft should be at least 10in.

5. *Flywheel.*—The flywheel of a Diesel engine, like that of a gas engine, must contain sufficient energy to maintain the velocity fairly constant in spite of the want of uniformity of torque indicated in Fig. 10. Four-stroke engines require

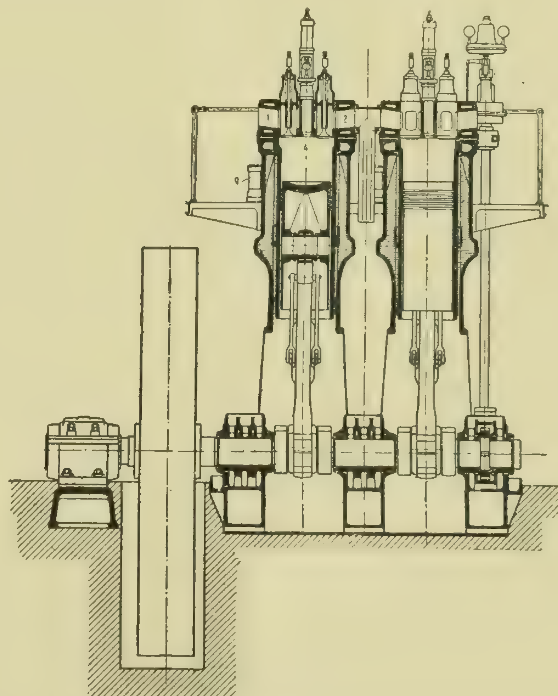


FIG. 13.

larger flywheels than two-stroke engines, and the fewer the cylinders the larger the flywheel must be. To give some idea of the size of the flywheel, it may be stated that a two-line, four-stroke, 250 b.h.p. engine, running at 200 revs. per minute, requires a flywheel weighing 15 tons, and since the weight of the engine itself is 40 tons, it will be seen what a large proportion the weight of the flywheel bears to that of the rest of the engine. The stored energy in this flywheel is

4,320,000ft.-lbs., or at the rate of about 17,000ft.-lbs. per brake horse-power. Owing to the want of uniformity of the torque, the fixing of the flywheel shaft has to be effected with special care.

6. *Framing.*—In Figs. 12 and 13 the A frames are of cast-iron box section, often fitted with splash guards, and this is the usual construction with slow-speed engines. Sometimes a single casting, forming a crank chamber, takes the place of the A frames when an engine has several lines; this is always the case with high-speed engines. Facings are machined at the feet to marry with the facings machined on the bed, and if the jacket cylinders are separate, facings have to be machined on the top of the A frames as well.

7. *Connecting Rods.*—Solid forgings of good quality carbon steel are used; the big end for land engines is generally of the flat-footed type to bolt on to the big end bearings or brasses. These brasses are often made of phosphor-bronze, but many makers use steel shells lined with white metal. The small end is often slotted out to carry a special split phosphor-bronze bearing, and a screw adjustment is fitted, so that the length of the connecting rod can be altered within small limits to adjust the compression accurately. When an open A frame is used, the lubrication of the small end is effected by means of a hole

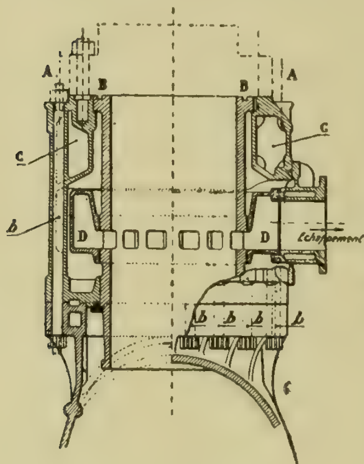
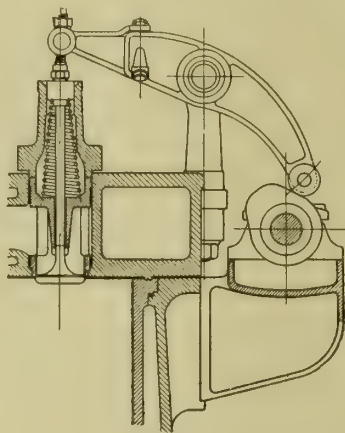


FIG. 14.


FIG. 15.

drilled through the gudgeon pin, which comes opposite a slot in the cylinder at the bottom of the stroke, and at this moment the lubricating pump squirts in a supply of oil. For the smaller engines a connecting rod of circular section is used; for high-speed engines, in order to obtain lightness and better distribution of the material, a round section with flattened sides is employed, and some makers have even gone to the expense of using flat rods milled out so as to obtain an H section, which, of course, is theoretically the best section for resisting the transverse inertia stresses. Such a section, however, can only pay commercially with high speeds and when great lightness is a necessity. The big end-bearing bushes are of similar design to those adopted for steam engines, the only difference being their greater weight for the same horse-power.

8. *Trunk Piston.*—The trunk pistons are made of cast iron, generally in one casting; they are ribbed inside for strength and for cooling, and a through hole is provided for carrying the gudgeon pin of the connecting rod, as shown in Fig. 11. The top is generally curved so as to relieve the stresses produced by the heat, and this shape of top has probably the effect of producing eddies, which increase the rapidity of combustion. This question of eddy-forming or turbulence is one which has only recently been noticed, and some experiments made a short time ago by Mr. Dugald Clerk and Dr. Bertram Hopkinson showed that in the case of the gas engine it is a most important factor in promoting rapidity of explosion. This is a matter which will have to be studied more closely in connection with the Diesel engine.

The maximum diameter of trunk piston that can be safely run without water or oil cooling is 24in. Above this diameter it is necessary to arrange for a water circulation or for an oil circulation. Messrs. Sulzer adopt an arrangement whereby oil is squirted on to the under side of the piston at the top of the stroke; the oil then falls in a shower into a cup, whence it is conducted to the connecting rod to lubricate the small end.

The piston body is grooved for the piston rings, and is extended to form a guide. There are also grooves without rings placed at the bottom of the extension to hold the lubricating oil. Messrs. Krupp and Messrs. Sulzer water-cool the piston in large engines. The large marine engines of the Maschinenfabrik Augsburg-Nürnberg Company are oil-cooled. The gudgeon pin is made of case-hardened steel, and is fixed in the piston body. Special care has to be taken to ensure that it is accurately placed in the piston body so as not to produce any cross strains, either in the piston or in the connecting rod, and these arrangements have to be such that the pin can be easily withdrawn for repair or renewal. Usually the length of a trunk piston is 1·8 times the diameter. A considerable clearance has to be allowed between the piston body and the cylinder; only experience can tell what this amount ought to be.

9. *Piston Rings.*—These are of the usual Ramsbottom type placed in the grooves in the piston body. Messrs. Sulzer adopt a special arrangement for machining these piston rings to get uniform pressure at all points; it is the same arrangement which they have adopted for years for steam-engine piston rings.

10. *Cylinders and Jackets.*—The general design of these has already been referred to, and can be seen from the figures. When the jackets are separately cast they are flanged at the lower end to bolt to the top of the A frame. Great care must be taken to machine these facings truly perpendicular to the axis, else difficulties will arise in running the engine. The studs have to be very large in the case of a 20in. cylinder, for example eight studs, 2½in. diam., are required. A special cast-iron mixture, suitable for resisting high temperature, is required for the cylinder liners.

11. *Cylinder Cover.*—The cylinder cover is cast with the water-jacket, and is arranged for taking the valve seatings of the air, fuel, and exhaust valves. There are through holes in the cover to take the long studs fixed in the top of the jacket.

Fig. 14 shows a form of construction recommended by N. Brosne for cylinders in order to minimise the effect of the exceptional stresses due to possible explosion (instead of combustion), which may cause pressures of from 100 to 150 atmospheres in a cylinder. The cylinder head consists of a flat plate stiffened by radial and circumferential ribs arranged so that the seatings of the various valves can be placed between them. The head is closed over with a light steel cover, thus forming a space for the water circulation. There is a stiff ring of hollow section placed around the top of the cylinder and carrying the studs for bolting on the cylinder cover. This ring is connected to the framework by long steel bolts, which, by their elasticity, take the shock of any exceptional explosion, and at all times relieve the cylinder walls of tensional stress, a matter of importance in two-stroke engines having exhaust openings through the cylinder walls at the bottom of the stroke when these walls carry the stresses.

12. *Two-to-one Shaft.*—The two-to-one shaft, or cam shaft, which is, in most engines, fitted in bearings carried on brackets, either bolted or cast with the jackets, approximately at the level of the top of the cylinder, is driven by helical gear from the crank shaft by the intermediary of the vertical shaft, the gearing being such as to reduce the speed in the proportion of two to one, so as to give a proper sequence for the four-stroke cycle. In some cases the cams are ground to the proper shape after being keyed on the shaft; other makers grind the cams to a "former," and thus obtain satisfactory results. In some of the larger engines the two-to-one shaft is run in an oil bath. In the American type of engine the cam shaft is placed inside the engine, as shown in Fig. 11. In the marine Maschinenfabrik Augsburg-Nürnberg engine the cam shaft is placed on the top of the engine, but in this case it is a two-stroke engine, and the cam shaft runs at the same speed as the crank shaft.

13. *Levers for Actuating the Valves.*—Ordinary levers of the first order are used; they have to be very stiff, as the forces at work are considerable, and there must be no perceptible deflection, or else a true opening in the valve would not be

obtained. At the cam shaft end there is a roller, and at the valve end a rocking pin with a round-end bearing in a cup on the top of the valve spindle. These levers are made of cast iron or malleable cast iron or of steel. In many designs a hinge is arranged so as to throw back the lever when it is desired to lift the valve. This is an important detail for overhauling, and is illustrated in Fig. 15.

14. *Special Lever for Starting.*—This lever works the air valve, which is fixed generally to only one cylinder. Whilst the engine is running it is out of action. For starting the engine its roller is brought into contact with a special cam, by means of a lever, and is thrown out of action again so soon as the engine begins to work on oil.

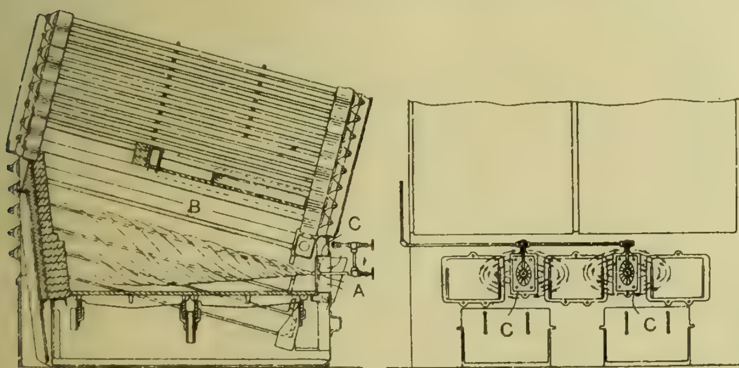
(To be continued.)

APPARATUS FOR BURNING FINELY-DIVIDED FUEL.

THE arrangement illustrated has been primarily designed to adapt so-called "round flame" burners employing finely-divided fuel to special furnace conditions wherein a broad flattened flame is desired. The burner is arranged in operative relationship with a casing or frame having an opening for the admission of air for combustion, this opening being larger in one direction than the other.

Figs. 1 and 2 show the arrangement, which has been patented by Messrs. Babcock & Wilcox, Ltd., applied to a boiler furnace of limited head room and great width. The use of a burner in this form of furnace giving a conical flame circular in section is objectionable for the reason that the flame comes into interference with the floor of the furnace and the water-heating surfaces forming the upper portion thereof, particularly at the entrance. With this form of furnace it is desired to spread the flame from the burners across the furnace in the direction of its width without using an excessive number of burners, or burners which in themselves produce a broad flat flame. Any suitable form of burner A may be used which will properly project a finely-divided fuel such as gas, oil, or solid fuel in the form of a substantially conical flame, into the combustion chamber B.

In order to flatten the flame, which would ordinarily be produced by the burner, the air for combustion is admitted through an opening which is longer in one direction than the other and which permits the entrance of a larger volume above and below the flame than is admitted at the sides. This is accomplished by setting a box or frame C having an oblong or oval opening into the furnace wall, the burner A terminating in proximity to this opening, as shown in Figs. 1 and 5, and substantially coincident with the axis thereof. The



FIGS. 1 AND 2.—ARRANGEMENT OF FURNACE FOR BURNING FINELY-DIVIDED FUEL.

volume of air admitted above and below the flame is greater than at the sides and this has the effect of pressing upon the upper and lower sides of the flame and flattening it horizontally.

Fig. 6 shows diagrammatically the effect of admitting air for combustion through a circular opening D, equal in volume at all points around the burner. In such case the flame will spread out in a conical form, circular in section, as indicated by the arrows. With the major axis of the air opening vertical, as shown diagrammatically in Fig. 8, the flame will be flattened as indicated by the arrows; that is, with its major axis horizontal. If the air opening is so placed that its major axis is horizontal, as shown in Fig. 7, then the flame will be narrowed horizontally and increased in height, as indicated by the arrows, that is, the flame will be of oval shape with its major axis vertical. As shown by Figs. 7 and 8, the major axis of the flame will be practically at right angles to the major axis of the opening for air admission.

If it is desired to give to the air for combustion a whirling or rotating motion, there is placed within the opening a series of blades inclined at an angle to the plane of the opening. A convenient way of doing this is to make the blades in the form of a plate, either a casting or blades of sheet metal secured to a suitable base. In Fig. 3 the blades E are secured at their inner ends to a central ring to provide an opening through which the fuel may be projected, and at their outer ends to an oblong frame or plate F. By using such a device the flame is not only flattened by reason of the oblong form of the air opening, but the air for combustion is deflected from its normal direction of travel and given a whirling or rotating motion by which are secured a continuous, uniform, and intimate mixture, making thereby a solid flame.

FIG. 3. FIG. 4. FIG. 5.

Instead of an oblong plate, an oval opening in a plate G may be filled with blades H inclined to the plane of the plate, as shown in Fig. 4, to deflect the air and to give it a whirling or rotating motion. In this case, as with an oblong or oval

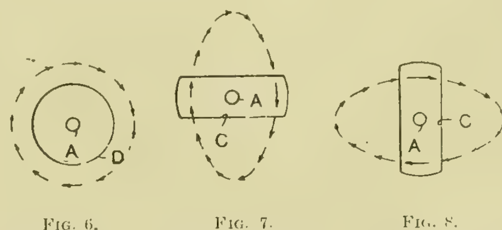


FIG. 6. FIG. 7. FIG. 8.

opening without the blades, the greater volume of air admitted at one point than another produces a flattened flame. In Fig. 5 is shown a box J rectangular in vertical section which may be set into the furnace casing and which has at the furnace end thereof a grating of vertical blades K inclined to the plane of their supports so as to deflect the air without giving it a whirling motion. All of these forms of openings, in which the area for air admission is longer in one direction than the other, produce substantially the same flattening effect on the flame. The major axis of such openings may be vertical or horizontal, or in any other position, to produce the flattening in the desired direction.

The Iron and Steel Institute.—The following changes have taken place on the Council of the Iron and Steel Institute consequent on the death of Mr. W. H. Bleckley, hon. treasurer: Mr. W. Beardmore, vice-president, appointed hon. treasurer, and Mr. J. M. While, member of Council, elected a vice-president, to fill the vacancy thus created. Lord Airedale of Gledhow has been elected a member of Council in lieu of Mr. While.

The Concrete Institute.—A course of six educational lectures on "Concrete: Its Properties and Manufacture," will be given by Mr. H. Kempton Dyson, Secretary of the Concrete Institute, at 5-30 p.m., on November 12th, 19th, 26th, December 3rd, 10th, and 17th, 1912. The lectures will be given in the lecture hall of the Concrete Institute, at Denison House, 296, Vauxhall Bridge Road, Westminster.

Collapse of a Crane.—A two-ton crane collapsed on Monday last at the top of the Tyne Commissioners' Offices in Bewick Street, Newcastle, where building extensions are in progress. The accident occurred while the men were at work. The crane was fixed at the top of a gantry, about 30ft. in height, and a load of material was being raised when the crane toppled over, and fell with a loud crash on the flooring of the top storey. The men who were working it had narrow escapes.

ON A NEW METHOD OF REVEALING SEGREGATION IN STEEL INGOTS.*

BY SIR ROBERT HADFIELD, F.R.S.

In presenting this paper the author suggests that it should be considered with and as bearing upon the subject of his paper on "Methods of Producing Sound Ingots," contributed to the present meeting. The reason for this is that the research now described appears to offer the means of throwing light upon the complex problems met with in relation to the production of sound steel by methods in which segregation and piping troubles, if not entirely absent, are largely reduced. In sound steel which pipes, unless steps are taken to deal with the troubles which accompany such piping, the difficulties of segregation in ingots which are not properly fed has not perhaps altogether been appreciated, as will be seen from the experiments now described.

Whilst knowledge has long been sought as to the changes which take place in the interior of masses of steel during cooling down from the molten to the solid state, few experiments of a definite nature have been undertaken. This has been the more unfortunate because steel of any nature or type, whilst so cooling down, is subject to the development of defects of a somewhat serious character. These chiefly come under the terms "segregation" or "segregated areas," and are largely due to the fact that the two chief deleterious elements, sulphur and phosphorus, always present in steel to a greater or lesser extent, liquate and separate out from the mass in those portions of the ingot or casting which remain



FIG. 1.—Fracture at Base of Head. FIG. 2. 4in. Below Head. FIG. 3. 8¾in. Below Head.



FIG. 4. 14¼in. Below Head. FIG. 5. 17in. Below Head.

Experiment No. 5893.—2½in. ingot (square) showing where copper penetrated. Total length, 30ins.

fluid for the longest period of time during the cooling down to the solid condition. Carbon and manganese, also to some extent nickel and chromium, also liquate, but they are not directly harmful in the same way as the two elements mentioned.

In other words, it is well known that at a certain stage of the cooling-down process of molten steel the complex phenomenon of liquation is met with and causes much difficulty. Possibly this phenomenon is more marked in its harmful characteristics in iron and its combinations known as steel than in any other metallurgical product. This is no doubt to some extent due to the high temperature which is necessarily employed during the manufacture of steel, which varies from probably about 1,400° C. in alloy steel, such as manganese steel, to about 1,650° C. in molten steel of mild quality. This difficulty is intensified because of the peculiar behaviour of the elements present. Whilst sulphur and phosphorus give the most trouble, the above remarks also apply to the element carbon and the metal manganese alloyed with iron, and, as above mentioned, to a less extent as regards nickel and chromium. This segregation of the elements referred to gives a brittle, impure, and weak steel, which in the finished article may prove not merely objectionable but dangerous. There is no proof that segregation occurs in fluid steel itself, that is, all the elements are then well fused and not segregated; the difficulty begins as soon as the mass commences to cool down; in other words, segregation appears to be a function of the lowering of the temperature. Whether this arises owing in some way to the lowering of the tension of combination of the molecules, if one can use this term, is not certain. In any case, however, the difficulty experienced seems to be almost entirely confined to the steel remaining liquid to the latest stage, probably partly through want of ferro-static pressure occurring in the centre of the mass. Thus, a steel of otherwise suitable composition, that is, sufficiently low in the deleterious elements sulphur and phosphorus, when cooled down will show, upon analysis, an increase of these elements at the segregated areas in some cases amounting to seven or eight times the original percentage. A sample of steel taken whilst fluid from the upper portion of an ingot is equally as pure as the lower portion. The difficulty only arises on cooling down, and in that portion of the ingot or casting where the ferro-static pressure is lowest.

Such segregated area if not removed remains in the casting, and becomes drawn out during the forging or rolling, or whilst being otherwise manipulated; thus seriously weak places mechanically will occur in the finished article. In some cases these defects get removed; for example, gun ingots are cast solid, and are afterwards usually bored out to remove the segregated areas. But this cannot be done in forgings requiring a solid section, so that the centre of disturbance remains present in such areas, in some cases giving rise to the production of articles possessing serious internal weakness which may break, if not at once, later on in service. This has, for example, been noticed in the case of rails, and dangerous accidents have resulted through their breakage.

The author thought that if it was possible to find means of ascertaining how this segregation arises, useful information would be obtained and methods of investigation opened up by which the difficulty could be dealt with and overcome. He therefore presents the results of this research and the methods adopted, which to his knowledge have not before been tried. They are simple, and yet by their use afford considerable information in the desired direction, that is, they show, to some extent, what is going on inside the molten mass during the cooling portion of the process.

The research commenced in this manner. It was reasoned that possibly some addition, preferably metallic, could be made to steel whilst in its molten or partly fluid condition which would give the desired effect. Thus upon breaking up the ingot when cold, if it would show the presence of the added metal in some clear and definite manner, such as by difference in colour, useful information would be obtained. The author, therefore, after a considerable number of experiments with various metals, selected copper, which, by its slightly higher specific gravity as compared with iron, would have a tendency to fall or drop down the central portion of the ingot being experimented upon; moreover, by its distinctive colour at the parts where it is alloyed with the iron its presence would be apparent.

In the first instance (Experiment No. 5,893, Figs. 1 to 5), a small ingot 2½in. square and about 30in. in length, was poured into an ingot mould in the ordinary way. The composition was: Carbon, 0·41 per cent.; silicon, 0·53 per cent.; manganese, 1·32 per cent. This ingot was furnished with a sand head, as shown by Fig. 6, the object of the sand head being to feed the shrinkage taking place in the remaining portion of the ingot. In other words, the ingot mould itself being of cast iron and the ingot head of sand, the molten metal in the latter remains fluid for a much longer time and helps to feed the shrinkage or contraction of the remaining portion of the ingot when it cools down to the solid condition. A similar method of overcoming piping with a suitable arrangement for carrying on the compression during cooling is dealt with very fully in the paper on "Method of Producing Sound Ingots."

Soon after the small 2½in. ingot was cast, a few ounces of molten copper was poured into the centre of the hollow space remaining in the sand head, about 1½in. from the outside. The time which elapsed between the casting of the ingot and the pouring on of the copper into the hollow space was approximately 30 secs. In this case, the result of pouring the

* Paper read before the Iron and Steel Institute, October, 1912.

molten copper, which was added in a comparatively cool condition, that is, it was not as hot or fluid as it should have been, appeared to be to chill the upper portion in the sand head. At first it was thought the copper had not penetrated the molten steel of the ingot at all. However, on breaking off the ingot head and making a longitudinal fracture, it was discovered that the copper had forced its way through a hole in the centre of the ingot of very small diameter, and penetrated nearly the *full length* of the ingot, an interesting result and somewhat unexpected. Figs. 1 to 5 show the appearance of the ingot when it was broken up under the hammer. The cuprous areas are indicated in black as they appeared in the fractures of the material.

The copper had penetrated into those portions of the ingot where piping usually takes place, and thus indicated the exact location where what may be termed inter-crystalline unsoundness or segregation is developed. It may be mentioned that this particular type of inter-crystalline unsoundness is not usually seen or detected in the fracture of an ordinary ingot when cold; it is only revealed by a polished section after etching. The cuprous areas in these small ingots probably represent these segregation areas.

This experiment showing interesting promise, the research was continued on several ingots 6in. square, each about 3½ft. in length, and weighing about 4 cwts. The design of these was similar to the small ingot just referred to, that is, the ingot itself was cast in an iron mould with the head portion of sand.

Into the head of the first 6in. ingot, No. 7455/1978A, 15lbs. of fluid copper, previously melted in a plumbago crucible, were poured half a minute after casting. The addition of the copper was carried out somewhat earlier than at first intended, because in the previous experiment on the ingot of small size the copper appeared to cause the steel in the head of the ingot to set. In the case, however, of the 6in. ingot, the copper did not cause the steel in the head to set as expected; most of it descended by its superior gravity almost bodily to the lower portion of the ingot. This ingot was parted into two portions so as to give a central longitudinal section; the section was then etched. Fig. 6 shows the appearance of the ingot, the dark portions being those coloured by the added copper. From the results obtained it will be noticed that half a minute after casting the ingot appears to have set to a thickness of about ⅝in. to ⅞in. along the sides and ⅞in. on the bottom. In the cuprous areas will be noticed crystals which have the same appearance as the outside envelope.

As in this 6in. ingot the copper was found to have been added somewhat too soon to give a full indication of what occurred on the steel reaching its setting- or chilling-point, the experiment was repeated on an ingot made from Heat No. 7501/1978A. In this case 15lbs. of molten copper was added after a period of 3½ mins. had elapsed after casting. This steel settled well in the sand test, also in a 2½in. ingot made at the same time, but the larger ingot was not quite sound. This was not, however, in any way due to the added copper, but to the interior of the mould being slightly damp. The experiment was repeated on a perfectly sound ingot and the results were the same. It was thought, therefore, interesting to present the unsound ingot to show that the same law applied to unsound as to sound steel. The dark areas in Fig. 6 show the cuprous portions of the ingots. These portions are indications of the state in which the interior portion of the ingot existed 3½ mins. after casting. After such a comparatively long interval of time, and in such a small ingot, it is somewhat remarkable that the copper should have descended so deeply. If the copper is added too early, that is, before the steel solidifies, it displaces or penetrates the molten material remaining. If the copper is added when solidification is completed, then it does nothing more than fill up the cavities, or strengthen segregation areas which are not really mechanically solid.

It would appear from these experiments that a valuable source of information is opened up for making tests with regard to rates of cooling, segregation, and liquation. Moreover, these results show that the interior of an ingot, even of small size, and it will be therefore more so in a large ingot, remains hotter for a much longer period than has been thought to be the case. It can, therefore, be more readily understood why segregation proves so harmful, for, owing to this longer time of cooling and the reduction in the ferrostatic pressure, naturally much greater opportunity occurs for the liquation of such harmful elements, sulphur and phosphorus. The more quickly the steel sets, the less opportunity is therefore given for this segregation. This fact has long been known in a practical way, but the reason for it has

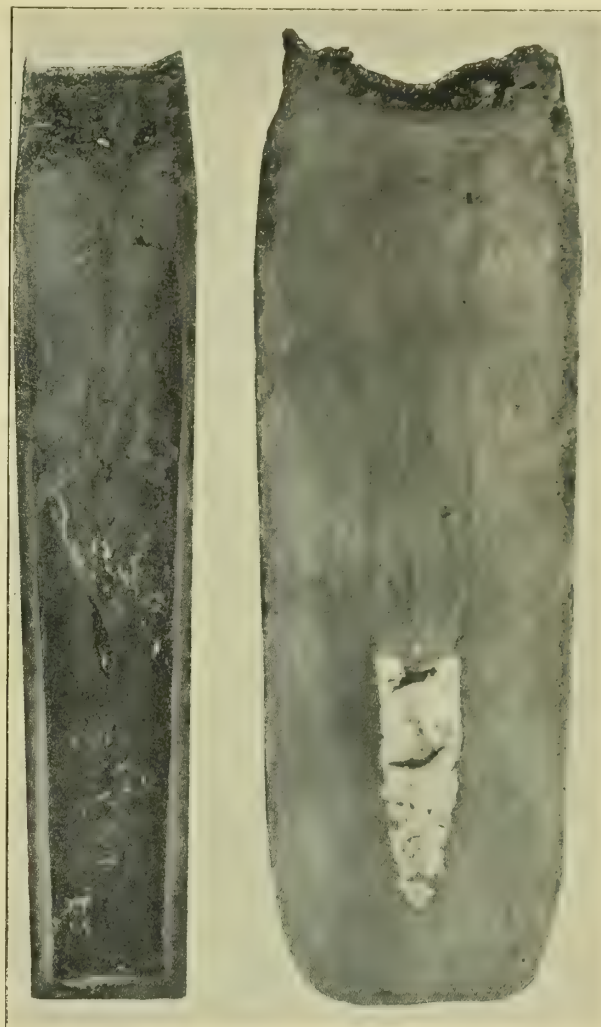


FIG. 6. Dark Areas showing penetration of Copper in ingot.

FIG. 8. Ingot (14in. diam.), into head of which 28lbs. of molten copper was poured 15 minutes after casting. Notwithstanding this comparatively long time, the copper is seen to have found its way almost to the bottom.

not been so apparent. The results of the present experiments seem to clearly indicate why quick cooling is advantageous. The following are comments upon the various figures:—

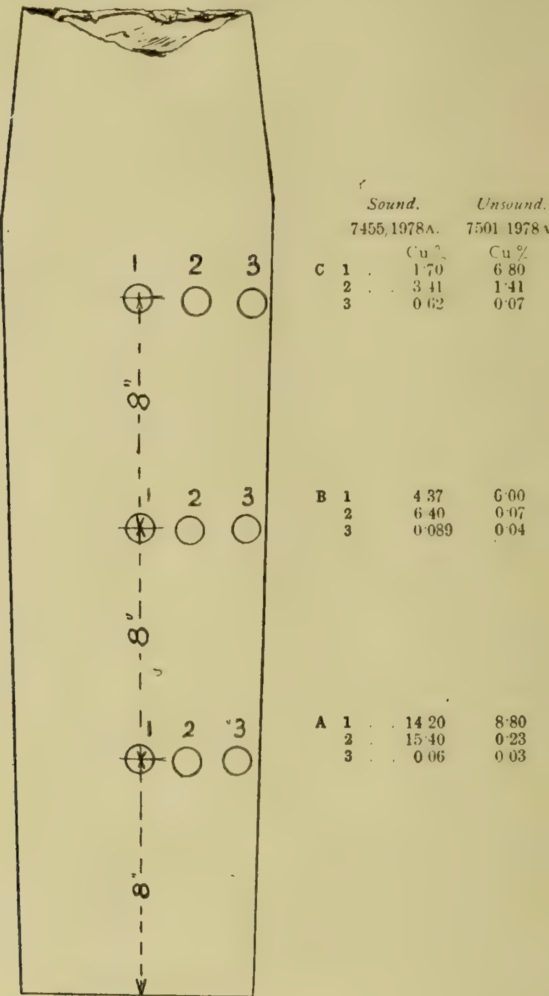
In Fig. 7 are shown the percentages of the copper found at the respective portions of the ingots Nos. 7455/1978A and Nos. 7501/1978A, as marked, described earlier in the paper.

A sulphur print taken from ingot No. 7455/1978A clearly showed the distribution of copper, the cuprous portions being lighter in colour than those which are free from copper. It was noticed that the acicular crystallisation of the copper free envelope ends abruptly where it joins the cuprous interior. In the cuprous portion the sulphur is evolved from innumerable small points, whereas in the copper free envelope the sulphur is evolved quite differently, giving an even brown colouration.

A sulphur print of ingot No. 7501/1978A showed the crystalline structure remarkably well. The print examined with a magnifying glass showed that the sulphur is evolved from innumerable minute points, and these points often run into lines parallel to the needle-like crystals formed in the matrix of the ingot.

Fig. 8 shows a larger ingot of about 14in. diam., into the head of which about 28lbs. of molten copper was poured

15 mins. after casting. The head was then covered with charcoal, and was not afterwards disturbed. The ingot was allowed to remain in its mould for one hour. The material was annealed and a section prepared, sulphur printed and etched. The copper was found to have penetrated to within about



		Sound. 7455/1978A. Cu %	Unsound. 7501 1978A Cu %
C	1	1·70	6 80
	2	3 41	1·41
	3	0 62	0·07
B	1	4 37	6·00
	2	6 40	0·07
	3	0·089	0·04
A	1	14 20	8·80
	2	15·40	0·23
	3	0 06	0 03

FIG. 7.—Section of one of two different 6in. Ingots of the following composition, showing the Percentages of Copper at the different portions of the Ingots.

Analysis of the Steel in these Ingots.

Ingot No.	Carbon per cent.	Silicon per cent.	Sulphur per cent.	Phosphorus per cent.	Manganese per cent.
7455/1978A	0·45	0·36	0·060	0·061	1·19
7501/1978A	0·42	0·42	—	—	1·34

9in. of the bottom, as will be seen, thus showing that even 15 mins. after casting the ingot was fluid at this point, and was readily permeated by the copper.

The examination of the sulphur print showed that there appeared to be some segregation at the bottom of the cuprous area. The cuprous portion could be picked out by the somewhat different appearance to the rest of the section.

It may be interesting to state that the relative contraction of copper and steel is as follows:—

	Copper.	Steel.
Expansion coefficient, solid	0·00001678	0·000011*
,, ,, molten	No data, but higher than for the material in its solid condition	
Specific gravity, solid	8·95	7·85
,, ,, molten	8·21	6·88†
Total casting shrinkage down to ordinary temperature...	1·42	1·50

* Mild steel. † No. 4 "Cleveland" foundry iron, which is ·95 when solid.

The molten specific gravities represent figures quoted in the "Standard Handbook for Engineers," from researches of Roberts-Austen and Wrightson.

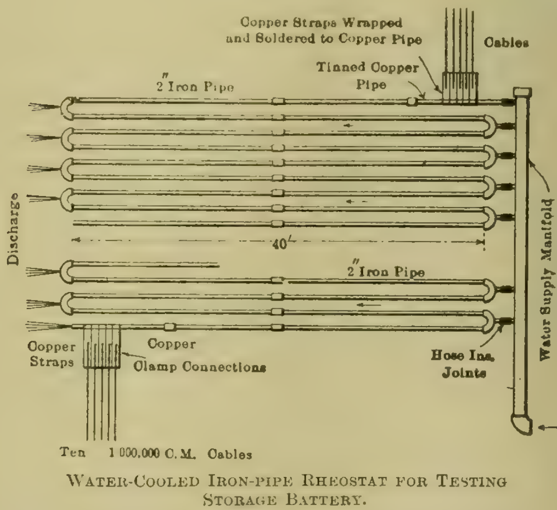
Probably what has occurred in the ingots described is that upon adding the copper which is poured on to the top of the ingot a pipe is formed, and the copper is forced into this by pressure. As the ingot cools down, more pipe is formed; the copper still remains fluid, and keeps such pipe portion filled. As, however, the copper contracts more than the steel, the cavity formed by piping draws upon the supply of molten copper at the top of the ingot. This expands or rises slightly upon setting; nevertheless it contracts more than the surrounding steel. Apparently the contraction of the copper and iron do not take place in the same relative proportion as might be expected.

In conclusion, the author thinks that these experiments should throw some light upon the nature of the phenomena occurring in the cooling down of molten steel to the solid condition.

A LARGE WATER-COOLED IRON-PIPE RHEOSTAT.

FOR testing a large sub-station storage battery at St. Louis it became necessary to provide a rheostat capable of dissipating continuously the power represented by 5,000 amperes at 300 volts. A water-cooled pipe-grid type of resister was decided upon, the iron pipe to act as the conductor while being cooled by a flow of water. Preliminary experiments and calculations indicated that about 600ft. of 2in. pipe would be required. The rheostat was assembled as shown in the sketch, for which, along with the accompanying description, we are indebted to "The Electrical World." Forty-seven 20ft. lengths of double-strength 2in. pipe were coupled in 40ft. pairs and connected by standard pipe returns, making a total length of 569ft. of pipe. It was soon found that the rheostat could not be cooled sufficiently by passing water from end to end through the 569ft. of pipe, so it became necessary to tap holes in the return fittings, threading one set and inserting nipples to hold the hose connections to the manifold water-supply pipe. From the other ends the water was allowed to escape and waste.

A serious problem was next presented in making an adequate connection between the battery leads and the iron pipe. The connections between the battery bus and rheostat consisted of ten 1,000,000 circ. mil cables 30ft. in length on



WATER-COOLED IRON-PIPE RHEOSTAT FOR TESTING STORAGE BATTERY.

each polarity. The attachment was made by bending ten 4in. by ¼in. copper straps around a 1in. copper pipe, soldering them to its tinned surface. To the flat lugs thus provided the cables were securely clamped. An ordinary pipe fitting connected the copper tubes with the main rheostat pipe. Water circulating through the copper kept it at a workable temperature and prevented the solder from melting. With this rheostat the 5,000 amperes output of the battery was satisfactorily dissipated during the rated one-hour discharge, 1,310 cub. ft. of water being used for cooling. Local hot spots in the pipe were quenched by playing with a hose or loading on snow. The pipe grids rested on bricks placed on sawhorses to prevent the wood from charring.

For a six-minute test of the same battery at a discharge rate of 21,000 amperes, two 3in. pipe sections were connected in parallel, one section being 154ft. and the other 161ft. long. Resistance was cut out, as needed, by bridging short-circuiting copper straps across the iron pipe. For the six-minute test at an average 20,000 amperes discharge, 319 cub. ft. of cooling water was required. The rheostat was designed and the tests carried out under the supervision of Mr. K. H. Hansen, electrical engineer of the Union Electric Light and Power Company.

INTERNATIONAL ENGINEERING AND MACHINERY EXHIBITION, OLYMPIA.—III.

Messrs. S. Redfern & Co., Swan Lane, New Brown Street, Manchester, exhibit their well-known specialities in the shape of flexible metallic packings for engines, spiral split packings for pump and hydraulic work, R.R. red jointing for all kinds of steam, air, or water joints, "Methusalite" air pump or condenser valves for land or marine engines, and "Preservo"

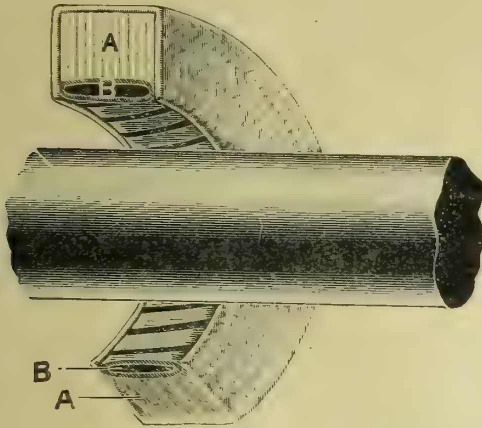


Fig. 1.—Metallic-faced Packing. Messrs. S. Redfern & Co., Manchester.

belt food, the latter being a perfectly harmless preparation for preserving all kinds of belting and enabling slack belts to transmit full load without slipping. Illustrations of three of Messrs. Redfern's packings are given in Figs. 1, 2, and 3, Fig. being the metallic-faced packing used for steam engines, pumps, and hammers, Fig. 2 the spiral split packing for hydraulic work, and Fig. 3 the "Wedge" self-setting steam packing. These packings are made in 10ft. and 15ft. lengths and for use lengths are cut off, so that when placed round the rod the ends do not quite meet. They are then rubbed with a mixture of graphite and cylinder oil, placed in the box, and the gland screwed down. The spiral split packing shown in Fig. 2 has been severely tested on hydraulic plungers at 2,000lbs. per square inch, and it is claimed has lasted longer than any previously used packing. Owing to its construction, it will be noticed that the pressure tends to keep the packing expanded between the rod and box, and a slight pressure on the gland also expands it.

When the "Wedge" packing is used the round section or cushion should enter the box first, the wedge which rests on the cushion coming next to the rod, and not less than three rings should always be used.

Another packing newly introduced by Messrs. Redfern and Co. is shown in Fig. 4. This is intended especially for

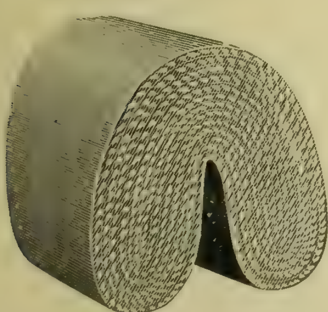


Fig. 2.—Spiral Split Packing. Messrs. S. Redfern & Co., Manchester.



Fig. 3.—"Wedge" Self-setting Steam Packing. Messrs. S. Redfern and Co., Manchester.

hydraulic work and is made of chrome tan leather. As will be seen, it is made in strips, the section of each strip being a bevel, the thin edge of each being laid alternately until the required size of packing is made up and then the whole is securely surrounded by a plaited covering to hold the strips together. It has been tested on all kinds of pumps using both hot and cold water, and is, it is claimed, quite suitable for use with petrol, paraffin, and ammonia. The packing also does not get hard after constant use, and being quite soft and flexible the gland only needs very slight pressure to keep it fluid tight.

Messrs. George Hatch, Ltd., of Queenhithe, Upper Thames Street, London, show a collection of machine tools including "Granat" shaping machines, plain milling machines, high-speed lathes, radial and sensitive drilling machines, ball bearing disc grinders, and spindle straightening presses. From amongst these we take for special description the "Express" radial drilling machine, and this we illustrate in Fig. 5. As will be seen, the main body casting is of box section and this is fitted with a substantial base, having T-slots planed out of the solid. The circular table is made to swing round quite clear of the baseplate when the latter is required for drilling large pieces of work; and yet, as will be seen, is always handy and convenient for use for smaller articles. The machine is fitted with wheel and lever hand feed as well as power feed, a balanced spindle, quick return, and a complete tapping and reversing motion. The gear gives nine changes of speed, they being changed by a simple sliding-key arrangement, and the head is travelled on the arm by means of the usual rack and pinion. The spindle has a radius of action of 3ft. 6in., its diameter being 1⅝in. and the socket 2in. diam. Spindle feeds with back gear are 17, 31, and 57 revs. per minute, and without the back gear 110, 198, and 357 revs. per minute, while the spindle feeds per revolution are ·004in., ·006in., and ·01in. The circular table is 24in. diam., and the working surface of the base is about 47in. by 27in. Altogether it is a well-

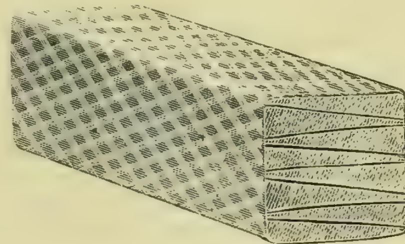


Fig. 4.—Chrome Tan Hydraulic Packing. Messrs. S. Redfern & Co., Manchester.

designed and powerful tool, while the workmanship and finish is everything that could be desired.

Messrs. Crown Works, of Chelmsford, show examples of their now well-known gauge sets, which we have previously described at length (see the "Mechanical Engineer" for October 21st, 1910, p. 509, Vol. XXVI), magnetic chucks of various forms and sizes, demagnetisers, small generators, rotary converters, surface plates, and a model of a neat design of setting-out table. It is only in recent years (at anyrate in this country) that people have begun to realise how convenient it is to hold iron and steel work for grinding or light machining by means of magnetic chucks, and yet it is almost impossible to accurately finish washers, saws, piston rings, and similar work unless they are held magnetically, and innumerable examples could be given where a great saving of time in clamping down is effected by using them. Several designs are shown, such as flat chucks for holding work on surface grinders, planers, &c.; special forms of flat chucks for finishing taper work, these being made to swivel lengthways on a suitable base, and adjustable to the desired angle by means of a knurled screw; and chucks for holding work on cylindrical grinders, in the lathe, &c. All are, it is claimed, absolutely waterproof, and the winding is so arranged as to afford the maximum holding power.

Hardened steel articles will, however, remain strongly magnetised after being held on a magnetic chuck, and in certain cases this may be objectionable. To overcome this difficulty the demagnetiser has been designed. This is supplied with continuous current, and to remove all traces of magnetism it is only necessary to pass the work over the top of the

table of the apparatus. It is a neatly-finished tool, the overall dimensions of which are 21in. by 14in. by 10in.

Messrs. The Power Plant Company, Ltd., of West Drayton, Middlesex, have a very large stand devoted to the exhibit of gearing and flexible couplings, in the production of which the firm have specialised. Amongst the gears shown may be mentioned a double-helical staggered-tooth type suitable for a

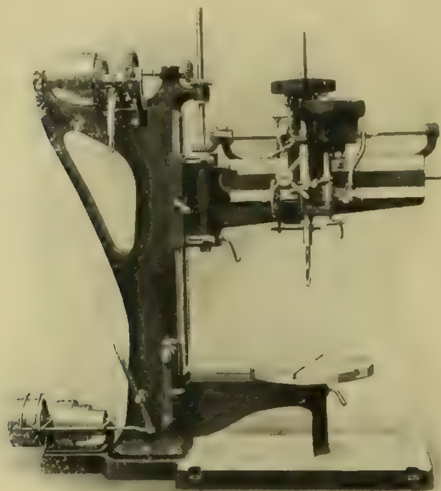


Fig. 5. "Express" Radial Drilling Machine. Messrs. Geo. Hatch, Ltd., London.

rolling mill and capable of transmitting 600 h.p. at 350 to 35 revs. per minute; triple-helical (continuous-tooth type) spur and bevel gears; and double-helical (continuous-tooth type) bevel gears. Single and double speed reducing and increasing gear was also shown in great variety and suitable for almost any class of work. Flexible insulating and reversing couplings are shown in 10 sizes, capable of transmitting from 3½ h.p. at 1,400 revs. per minute to 560 h.p. at 750 revs. per minute, and flexible couplings of the heavy duty type to transmit 400 h.p. at 350 revs. per minute. The insulating and reversing couplings have been specially designed for use in cases in which heavy shocks are met with and considerable overloads may have to be withstood, as on rolling mills, electric winders, &c. The flexible medium being in compression, the strength of the coupling is determined by the strength of the metal transmitting the power. In certain cases it is therefore advisable to make the couplings in steel which would of course be useless in many makes of coupling which are limited in capacity by the strength of their flexible parts. The firm, we understand, make them in sizes from $\frac{\text{H.P.}}{n} = 1{\cdot}25$ up to $\frac{\text{H.P.}}{n} = 48$, where n = the number of revolutions per minute. They can also be supplied with both halves solid or both halves with detachable bosses.

Messrs. Hindle, Maitland, & Co., of 100, Deansgate, Manchester, exhibit an electrically-operated press suitable for use in the packing trade and pressing industries. It is perhaps the most novel application of electricity to be seen at the Exhibition, and although it was shown at the recent Electrical Exhibition at Manchester, this is its first appearance in London. The press shown is a small one suitable for pressures up to about 30 tons, and is made particularly for packing cotton and woollen goods. The illustration, Fig. 6, shows the general arrangement, and it will be noticed how very compact and self-contained the machine is. No foundations are necessary, nor are there any water troubles, and its operation is simplicity itself. To compress, the switch is pushed up; and to release, it is pulled down. The current is, however, cut off at any predetermined pressure in tons, quite automatically, and this pressure is then maintained for as long as desired. A point which will appeal to the user is the economy of the press. The one shown in the illustration will bale 100 times working up to its full capacity for one unit, and this usually costs about one penny or less. A hydraulic press doing the same work would, we are informed, cost 50 times as much if connected to the London hydraulic power mains. In addition to an indicator directly recording the pressure, an ammeter is fitted which shows the current flowing at any particular instant, and another meter the total current consumed. Circuit breakers are used to stop the motor automatically at the desired pressure, and this pressure is then maintained by means of a simple brake on the motor spindle, which is only released by an electromagnet when the motor revolves. As will be understood, the motor only revolves during the actual period the press is being operated, and so only demands energy, at any instant, proportionate to the resistance offered by the material subject to pressure. This resistance is extremely low during the greater portion of the upward travel of the table or platen, and rises abruptly at the completion of the stroke. The motor adopted, being series wound, automatically runs three times faster at the commencement of the operation than at the conclusion, and only slows down towards the end of the stroke when the resistance of the material commences to suddenly increase.

Messrs. Hindle, Maitland, & Co. also show two electrical fires on their stand, which, owing to their neatness and low current consumption and price, should meet with favour.

Messrs. Lassen & Hjort, of 52, Queen Victoria Street, London, are exhibiting a complete Lassen & Hjort water softener actually in operation, and softening the London water supply from the mains at Olympia from 17 degrees of hardness down to 2 degrees at a cost of less than ½d. per 1,000 gallons, the water being delivered sparkling clear and perfectly suitable, not only for steam raising and industrial purposes, but also for drinking and domestic use. We understand that Messrs. Lassen & Hjort were the first to introduce the modern lime "milk" process of water softening, which revolutionised the older lime "water" treatment, and rendered possible the treatment of large quantities of water in a comparatively compact plant by means of an exact system of measurement of both the hard water and the chemicals required to treat it.

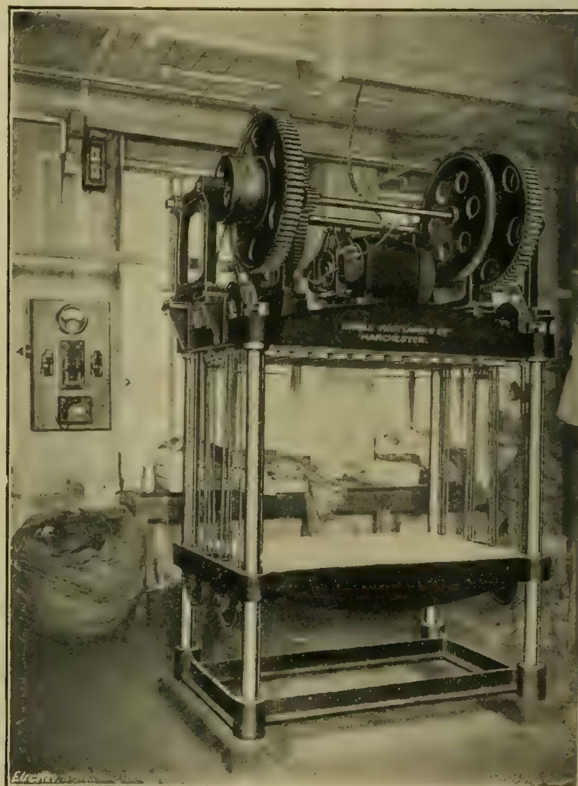


Fig. 6. Hindle's Patent Electric Baling Press.

The salient feature of the Lassen & Hjort system is the provision made for the exact measurement in small, definite quantities of hard water and chemicals, and even a cursory inspection of the plant makes it obvious that the patent measuring and mixing gear gives a degree of control over the softening process which must tend towards the attainment of great accuracy in treatment. In addition to the complete plant, the firm are exhibiting the measuring and mixing apparatus

of a large softener having a capacity of 20,000 galls. per hour, which could not, of course, be shown entire on the stand. Special attention is drawn to the patent positive chemical discharge valve with which the plant is fitted, which works in

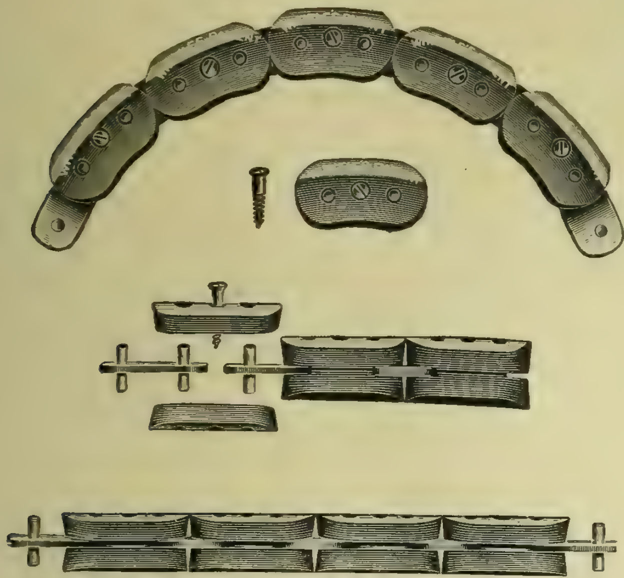


Fig. 7.—Whittle Patent Belting. Messrs. Thos. Whittle & Sons, Ltd., Warrington.

complete independence of the head of solution in the chemical container, thus making it possible to provide for the delivery of any desired quantity of reagent. Another interesting adjunct to this plant is the makers' patent locking gear, an ingenious arrangement by which the fall of the tipper is automatically retarded until the latter is completely full. The apparatus is thus made a perfect water meter, as the amount of water passing through the plant can be ascertained with the greatest precision by attaching a counter to the tipper shaft. A very neat and ingenious automatic water sampler completes the equipment of the plant.

Messrs. Thos. Whittle & Sons, Ltd., Rose and Crown Street, Warrington, exhibit their patent belting, the construction of which will readily be understood by reference to the accompanying illustration (Fig. 7). This is one of the best, in fact we might say it is *the* best belt for use in V pulleys we have come across. It is exceedingly flexible, can be run quite slack, and has great gripping power and strength, and one of its chief advantages is that it requires no fastener, as each link is in itself a connecting piece, and it can be shortened or lengthened in half a minute. In order to shorten the belt it is only necessary to remove a link at any point, and in cases where the drive is very short, and a full link would be too much to take out, short links are supplied for the purpose of better adjustment. The belt, it is claimed, is not affected by dust or grit, and works equally well wet or dry.

Messrs. Mayer & Schmidt, of Offenbach-on-Main, who claim to have the largest works for grinding machines in Europe, have a representative exhibit of their manufactures on Stand No. 252. Several of these machines are shown running, including one for automatically grinding the cylinders of motor-car, gas, gasoline, and Diesel engines, and suitable for cylinders up to 800 mm. diam. and 2,500 mm. long; another, known as an automatic link and bush grinder, fitted with planetary rotation of the spindle, for grinding straight and curved link motions and holes and bushes in locomotive and marine work; and a third for rectifying straight faces of locomotive parts, &c., such as slide bars, connecting rods, valve faces, and link motions, as well as for all other surfacing work, and especially the grinding of straight edges and surface plates of cast iron or cast steel. Automatic twist-drill grinding and saw-sharpening machines are also shown, together with grinding wheels and materials to suit all purposes. The saw-sharpening machines supplied by this firm will sharpen all kinds of straight-toothed cold saws, circular saws for wood, also bandsaws. Once set, the machine works automatically, grinds accurately and quickly, and offers therefore great advantages over handwork. The automatic backward and forward motion of the emery wheel, which is actuated from the inside of the column, can be regulated according to the size of the saw and height of the teeth from the outside by means of screws, so that the emery wheel can take a heavier or lighter cut. The automatic circular feed of the saw is also easily adjustable whilst the machine is in motion. This adjustment is used in order to grind off more from the front or the back of the teeth. For this machine extra hard emery wheels are supplied, which wear away very slowly.

Messrs. The United Motor Industries, Ltd., of 45-46, Poland Street, London, W., exhibit many interesting examples of the application of the well-known D.W.F. ball bearings, including grinder heads, lathe poppet heads, line shaft, bearing hangers, &c. A machine is also exhibited to show the excellence and hardness of the D.W.F. steel balls. This is actuated by air pressure, and by its means a ball is forced up a tube and on to a stage immediately above a hard steel plate. From this point it is allowed to drop on to the plate, and its rebounding indicates the hardness of the ball. On the stand a D.W.F. ball sorting machine is also to be seen at work, sorting balls according to minute differences in size. The balls are liberated one at a time, and roll down the edges of two steel blades, which are set *almost* parallel to one another, but with the wider space at the bottom. The balls, according to their size, drop off at various points, and are caught in a series of pockets below.

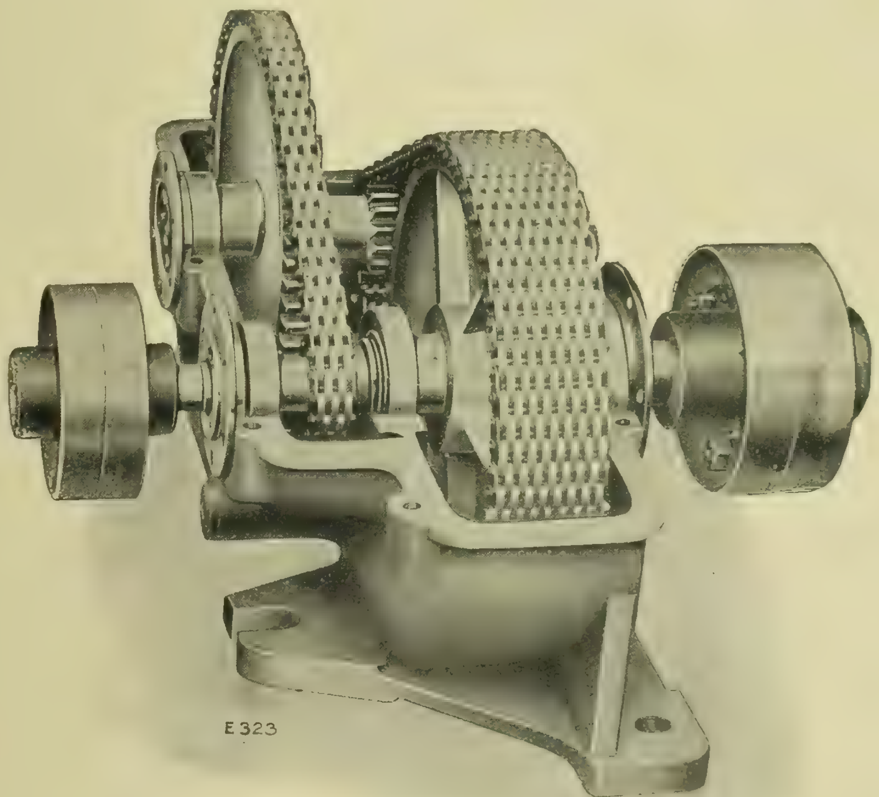


Fig. 8.—Speed-reduction Box, with Top Half of Case Removed. Messrs. The Coventry Chain Co., Ltd.

The accuracy of balls used in ball bearings is, of course, a matter of the utmost importance. It is held by many that

$\frac{1}{10000}$th of an inch is a permissible variation in the size, viz., diameter and sphericity of the balls, but the D.W.F. Company are at variance with this view, and rightly so. If $\frac{1}{10000}$th of an inch is the limit of tolerance, then the race or ball must deflect enough to allow for this difference, with the result that a bearing loaded up to its catalogue capacity is over-loaded in those balls that are larger, and progressive failure is the result. All balls used in the ball bearings made by the D.W.F. Company are therefore made and guaranteed to be within 0·0000197in. (under one-fifth of $\frac{1}{10000}$th of an inch) of each other as to size and sphericity. The accuracy observed in the manufacture of D.W.F. ball bearings is thus five times as great as if $\frac{1}{10000}$th of an inch were taken as a permissible variation. In addition to extreme accuracy great elasticity and hardness are two other essential features of a perfect ball bearing. Endless experiments have been made to determine the most suitable material, and it has now been found that a special form of chrome crucible cast steel is the ideal one. Chromium, as an alloy in crucible steel, imparts to it the property of exceeding hardness, great toughness, homogeneity, high resistance to shocks, and high elastic and tensile limits; it also prevents the formation of a crystalline structure, and renders the steel comparatively free from the liability of fracture in hardening. By the addition of a small percentage of vanadium, which has the valuable property of scavenging out the injurious oxygen and nitrogen, the dynamic strength of the steel is likewise increased. It is, we are informed, from a special chrome crucible cast steel, containing these alloys in their correct percentages, that the D.W.F. ball bearings are made (both balls and races), and as they number among their subsidiary plants two of the world's leading high-grade tool steel works, the steel thus obtained is always of the same quality, which is a matter of great importance to the consistency of the finished product. We may mention, in conclusion, as showing the output of the D.W.F. works, that the firm grind within 10 hours 60,000 balls of $\frac{1}{4}$in. diam., and the machines are so accurate that before the balls are sorted they already have an accuracy of one-half of $\frac{1}{10000}$th of an inch.



FIG. 9. "NOISELESS" CHAIN ENTERING THE TEETH OF A WHEEL. MESSRS. THE COVENTRY CHAIN COMPANY, LTD.



FIG. 10.—"NOISELESS" CHAIN, WITH CENTRE GUIDE PLATES TO RUN ON GROOVED WHEELS (IN THE STANDARD PATTERN THESE GUIDE PLATES ARE FITTED ON THE OUTSIDE). MESSRS. THE COVENTRY CHAIN COMPANY, LTD.

Messrs. The Coventry Chain Company, Ltd., of Spon End, Coventry, exhibit chains of every description for power transmission, including "Coventry" noiseless chains, roller and block chains, also a noiseless chain drive in motion from motor to line shaft, and roller chain drive from the line shaft to a "Coventry" speed-reduction box, which is actuated by noiseless chains, and gives a reduction of 32 to 1. Such a box we have pleasure in illustrating in Fig. 8. These gears, it should be noted, may be driven in either direction, and can be arranged with the lay shaft either in front or behind the driving and driven shafts. In other words, they may be either right or left handed to suit existing conditions, and are supplied as a standard with two flange couplings, one-half of each being bored to customers' specifications.

The "Noiseless" chain drive differs very materially in principle and action from that of chains of the roller and block type, and its many advantages over these vastly extend the field of application of chain as a power transmitter. Fig. 9 shows the action of the links when entering or leaving the teeth of the wheel, from which it will be noted that there is no sliding friction between the links and the teeth during the time of engagement. When new, the chain lies compactly between the teeth, but as the elongation of pitch, due to wear, which is inevitable, shows itself, the chain automatically accommodates itself to the teeth of the wheel, and hence the load is equally distributed between all the teeth that may at any moment be between the points where the chain enters and leaves the teeth. It is, of course, essential that the profile of the lower portion of the link is in perfect sympathy with the tooth form, for under such conditions only can an ideal drive be obtained. With the "Noiseless" type of chain it will be seen that the profile of the link (Fig. 10) is of a special form, and great care is taken to ensure the working angle of the link being absolutely correct, extreme care being necessary in drilling and reamering the holes in them. It will be noted that the links are arranged in pairs (Fig. 10), and these are held together by a dead hard bush forced into the reamered holes of each link, thus ensuring stationary and hardened bearings where most of the wear inevitably takes place. This form of manufacture produces a strong and rigid chain, and eliminates the liability of the bearing parts working loose. The double links are assembled alternately to form the various widths in combination, and the whole of these are kept together and work on hardened steel rivets, which are provided with washers at their extremities, as shown.

Messrs. The Metallurgo Syndicate, Ltd., of Balfour House, Finsbury Pavement, London, E.C., and **Messrs. The Patent Castings Syndicate, Ltd.,** of 64, Strode Road, Willesden Green, London, N.W., have a joint exhibit on stand No. 157. The former syndicate exhibit two of their specialities in the shape of Adamantium bronze—a high-class non-corrosive, anti-friction metal for bearings, gears, propellers, pumps, bushes, motor and lorry work, railway and marine fittings, &c., supplied in ingot, bar, rod, tube, sheet, wire, castings, &c., and "Ormolum"—a rich golden colour alloy, for high-class electrical, motor, yacht, architectural, ecclesiastical work, and fittings for doors, gates, grids, &c. It is supplied in ingot, bar, rod, tube, sheet, wire, castings, &c. The Patent Castings

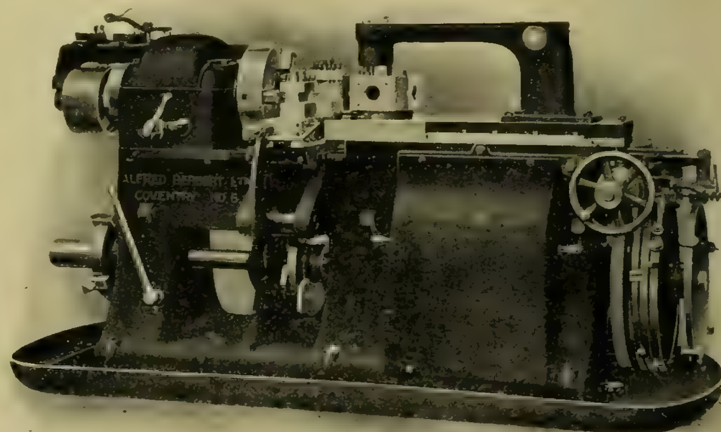


FIG. 11.—AUTOMATIC TURNING MACHINE WITH PATENT SELF-SELECTING FEEDS AND BACK-FACING ATTACHMENT. MESSRS. ALFRED HERBERT, LTD., COVENTRY.

Syndicate exhibit numerous examples of die castings, made by them in a variety of metals. Such castings represent one of the most economical and at the same time efficient ways of producing finished parts, and they are largely being used nowadays, and superseding the old-fashioned method of rough casting and machining. Screw threads, holes, &c., are cast equal to tapping or reaming, while interchangeability is secured with much more certainty than by machining, as all cast parts are exactly alike, and, being absolutely accurate, the time saved in assembling is considerable. No fitting work is therefore required, and the pieces only need assembling, even when there are several such castings in one piece of apparatus. For repetition work the cost is very much lower than by ordinary methods, and the more complicated the piece the greater is the economy of the process. Apparatus made in several parts in order that it may be machined can generally be combined into a single casting, thus considerably cheapening the article, and giving it a much neater appearance. A special feature also of their process is that, where necessary, brass, steel, or other metal pins, bushes, tubes, or other such parts, can be cast in, and many parts hitherto considered impossibilities owing to machining difficulties can now be readily made. Amongst the articles shown were gears of all descriptions, including spiral, bevel, internal, &c., typewriter, adding machine, phonograph, meter, and electrical instrument parts, as well as parts for safety razors, medical instruments, and automatic machinery in general. The castings shown are beautifully finished, and can, we understand, be nickelled, brassed, polished, or bronzed, or supplied with any other desired finish.

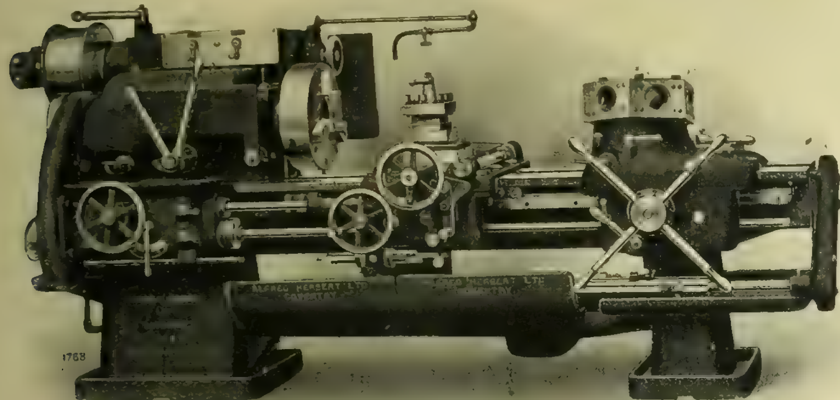


Fig. 12.—No. 9 Combination Turret Lathe. Messrs. Alfred Herbert, Ltd., Coventry.

Messrs. The Hoyt Metal Company of Great Britain, Ltd., of 26, Billiter Street, London, E.C., exhibit various qualities of their well-known standard babbitt (or anti-friction) metals, the range shown being sufficient to cover practically every bearing requirement in the way of lining metals. Amongst these we noticed their "copper-hardened," which is claimed to be the best anti-friction metal made and suitable for the heaviest pressure and highest speeds. This is a tin-base metal so blended with copper as to ensure the wear-resisting properties of the former with the toughness and tenacity of the latter metal. The firm's "Arrow" brand anti-friction metal is also shown. This is toughened with copper and antimony, and is likewise suitable for heavy pressure and high speeds, but is not recommended to withstand severe pounding or jarring, such as the above-mentioned copper-hardened will. Other grades exhibited are their No. 1, an excellent anti-friction metal for almost universal use, for heavy pressure and medium speed, or medium pressure and high speed; "Star" brand for medium pressure and medium speed, or light pressure and high speed, and especially recommended for railway carriage and wagon and tramcar bearings; No. 3 M, a metal of the magnolia type; No. 4 A, suitable for light pressure and medium speed, such as small engines, flour mills, light to medium shafting, caps for bearings, repair work, &c.; and No. 4, one of the cheapest metals on the market, but a good alloy for light services, and offered where the question of price is the prime consideration. The firm claims to be the largest and one of the oldest-established makers of anti-friction metals, and the output of their four works aggregates some 7,500 tons per annum.

Messrs. Alfred Herbert, Ltd., of Coventry, have two very large stands adjoining each other, and here are exhibited about 30 up-to-date labour-saving machine tools, both of their own make, and of those firms they factor. Seventeen of these tools are driven by independent motors, and the others from an overhead countershaft. On the smaller of the two stands machine tools are also shown in operation, together with a collection of miscellaneous small tools.

It is obviously impossible for us to more than call attention to most of these, but the three machines we illustrate and describe at length may be taken as typical of the others shown. Amongst the tools exhibited attention may be drawn to the following: A 12in. by 36in. universal grinder, the work head of which is reversible, one end being used for live spindle and the other end for dead centre work, the internal attachment being kept permanently in position ready for use; a ball-bearing twist drill grinder in which the spindle, countershaft, and loose pulley run on ball bearings and in which there is an automatic water supply without pump; a 3-spindle ball-bearing drill with one geared spindle, each spindle having four drilling speeds. Any spindle can be run at any speed without regard to the speed of the other spindles, the standard spindles drilling up to 1in. and tapping up to $\frac{5}{8}$in., and the geared spindles drilling up to $1\frac{1}{4}$in. and tapping up to $\frac{3}{4}$in.

Capstan, hexagon turret, and combination turret lathes are also shown, as well as other lathes for special purposes; together with grinding, drilling, boring, milling, gear hobbing, and shaping machines. In fact, a tool adapted to machine almost every job likely to be met with in the shops, and that in the minimum of time, and with the greatest accuracy and precision. Fig. 11 shows an auto-turning machine exhibited by Messrs. Herbert, Ltd. This is a tool having many distinctive features, amongst which we may mention the following: All operations are automatic except chucking; the machine stops automatically at the conclusion of the work; there is a patent self-selecting feed motion giving seven feeds to each cam, and no changing of cam angles

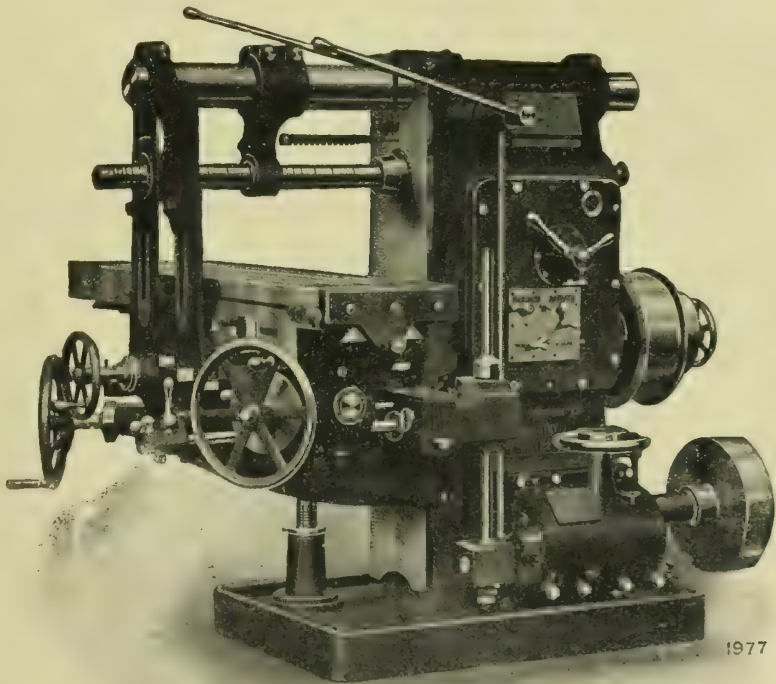


Fig. 13.—No. 22 Single-pulley Milling Machine. Messrs. Alfred Herbert, Ltd. Coventry.

are necessary to vary the feed; threading with a solid die can be done if required, and tapping can be done right or left hand with solid taps; the capstan has independent self-selecting dead stops to each tool, and there are two independent cross slides, working simultaneously when required.

The head, as will be seen, is a box casting, so that all the gears run in an oil bath, ensuring quietness and freedom from wear. Two ratios of gear are provided, the change from one to the other being made by the handle at the front of the head. The pulleys provide a total range of 16 spindle speeds with either a two-speed automatic change running in one direction, or a forward and reverse motion for tapping. Four ratios of automatic speed changes are thus obtainable without changing any pulleys or gears, the variable ratio being of great advantage when doing a variety of work on the same machine. The starting and stopping lever actuates a brake, which quickly brings the spindle to rest as soon as the belts are on the loose pulleys, and the loose pulleys running on annular ball bearings are therefore quite free from lubrication troubles. The belts are moved automatically on to the loose pulleys at the end of the cycle of operations, thus stopping the machine ready for taking the finished work out of the chuck and inserting a fresh piece. To restart the machine after chucking, all that is necessary is to trip the feed lever.

The capstan slide and its operating drum are adjustable by rack and pinion into various positions to and from the chuck, to accommodate work of varying length, and the top slide has an additional rack and pinion motion to facilitate tool setting. The capstan slide has self-selecting adjustable dead stops for

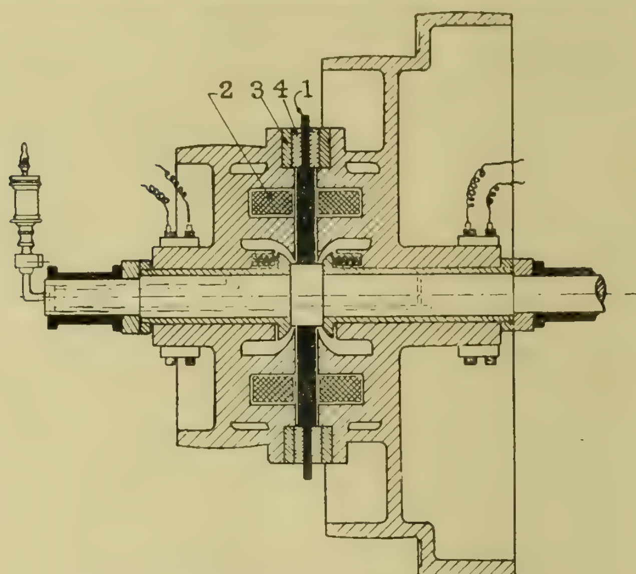


Fig. 14.—Vulkan Reversing Electro-magnetic Clutch. Messrs. C. E. Lugard & Co. Chester.

each tool, which are indispensable for facing to exact lengths and for preventing drills or boring tools from jumping forward and jamming when breaking through at the end of the cut.

The capstan, as will be seen, is square, its flat faces being accurately surfaced and scraped exactly square with the spindle. An overhead support makes it very steady, and a shock absorber relieves the indexing bolt of the momentum of the capstan when rotating. As a result of this and of other features in the design, the capstan indexes at a moderate speed and without any shock, and thus will remain accurate for years.

The patent "self-selecting" feed motion gives seven feeds for each cam, the changes of feed being made automatically as each tool comes into action. The range of feeds is thus sufficiently wide to provide for drilling hard materials out of the solid at one end of the scale, or for reaming with a coarse traverse at the other, so that the cam angles never need to be changed for varying work. The result is that a very great variety of work can be done with the standard cams, and each operation can be adjusted or "tuned" up to give the maximum output without affecting other operations. The feed changes are made in the following way: A disc at the right-hand end of the machine carries six adjustable change-feed dogs, viz., one for each tool. These dogs can be set anywhere round the disc. Each dog has seven holes corresponding to the seven feeds, and is provided with a pin which can be placed in the hole corresponding to the feed required. As the cam shaft rotates the pin automatically sets the feed before the tool begins to cut. It will be seen that the setting and changing of the feeds by this device are simplicity itself.

The feeds are driven from the headstock, but the quick or idle motions are driven by a constant-speed shaft at the back of the machine, and therefore never vary, the idle motions taking place always at the most efficient speed. The whole range of seven feeds can be raised or lowered in rate by change gears giving 14 feeds in all for each cam, and we understand further feed ranges of seven each can be provided by additional change gears when required.

Fig. 12 shows Messrs. Herbert's No. 9 combination turret lathe as exhibited. This is a massive tool, of the all-gear head type, and its general design will be understood by a reference to the illustration. Provision is made in this lathe for cutting right or left-hand screws, the leader being reversed by a lever in the feed box. The nut is also connected with the tool slide in such a way that when it is withdrawn from the leader by the hand lever on the saddle the tool or chaser is simultaneously withdrawn from its cut, and vice versâ, without either turning the screw or moving it endwise. The cross feed is provided with an adjustable graduated index disc, and by using this as a measure of the pressure on the dead stops very accurate diameters can be turned.

In addition to the chasing gear, the apron has interlocked automatic longitudinal and cross feeds. Automatic and dead stops are provided for both motions, there being eight in all. All the stops have fine adjustment screws, and the fixed stop on the feed box has an adjusting screw by which all the saddle stops can be adjusted in unison to suit variations in the work. The interlocking feature entirely prevents the possibility of damage by having two feeds, or the feed and the chasing gear, in operation at the same time.

The main turret, as will be noticed, is hexagonal. Box tools and cutter heads can be bolted to its faces, and boring bars, drills, and reamers can be carried by the tool holes, which also enable long work to pass clear through the turret. The turret is inclined so as to enable long tools to clear the pilot wheel. It is indexed by hand in either direction and can be rigidly clamped after indexing. The taper attachment will deal with either internal or external tapers, and taper threads can be chased as easily as parallel threads, owing to the fact that the tapering motion does not conflict with the quick withdrawing mechanism. This is an unusual feature, but is very valuable where much taper turning or threading is required. An indicator fitted to the machine enables dead lengths to be obtained within the finest limits of error. Its effect is to ensure absolutely uniform pressure on the stops independent of changes in the pressure on the cutting tools, as they become dull. It consists of a disc rotating with the pilot-wheel shaft on the turret slide. The disc carries three adjustable dogs having index lines upon them. The boss on the slide is furnished with a fixed disc marked with three lines to correspond with those on the dogs. When extreme accuracy is required one of the dogs is set so as to come opposite one of the index lines when the turret slide is held hard up against the dead stop. The dog thus forms an accurate means of securing uniform pressure on the dead stop.

Fig. 13 shows Messrs. Herbert's No. 22 single pulley milling machine. This has been designed for heavy milling and large output, and its general design will be understood by a reference to the illustration. At the Exhibition it was shown at work taking a heavy test cut on cast iron and using a cutter 8in. in width. It is fitted with automatic cross and vertical feeds, and all feeds have automatic stops in both directions. The auto-feeds are also operated by the firm's patent dial-feed motion.

Messrs. Henry Rossell & Co., Ltd., of Waverley Works, Sheffield, exhibit their "Victory" high-speed twist drills in great variety, and have on their stand several drilling machines in operation to demonstrate their claim that their drills possess the combination of toughness and great penetrative power. The firm make their own steel from which the drills are made, and, as showing the demand there is for them, inform us that they are at present building a larger factory in which is being installed the most up-to-date machinery for their manufacture.

Messrs. The Patent File and Tool Company, Ltd., of 8, White Street, Moorfields, London, E.C., exhibit a complete assortment of their now well-known "Dreadnought" milling files. These

files are to all intents and purposes hand milling or planing tools. They are made from a high quality Sheffield tool steel, the teeth being semi-circular in shape. This principle of the circular tooth, combined with an unbroken cutting edge, producing a shearing cut, is only found in the "Dreadnought" file. It will, it is claimed, cut everything, including iron, steel, brass, copper, tin, lead, babbitt metals, aluminium, horn, wood, marble, &c., and leave an absolutely smooth and finished surface. A working exhibition is also given of the method of re-sharpening or grinding these files, and public tests on the Herbert file testing machine are also given daily.

Messrs. David Hart & Co., of Wenlock Road, City Road, London, N., exhibit several types of weighing machines, in the manufacture of which they have specialised. Amongst these, we notice several sizes of portable machines and a 21 cwt. Dormant weighing machine, the latter being fitted with a ticket-printing apparatus attached to the steelyard. The chief advantage claimed for their machines is that they have no loose weights whatever, the goods on the platform being weighed by means of two sliding weights on the steelyard, one representing cwts., the other lbs., &c., or any other subdivisions. When these weights are both at zero they simply balance the weight of the platform and other working parts of the machine. To ascertain the weight of goods the large weight is moved along the steelyard until it almost balances the goods; the small weight is then moved along until a perfect balance is obtained, and the exact weight of the goods is then indicated by the position of the sliding weights, in cwts., qrs., lbs., &c., or in any system of weights desired, on a plainly engraved scale. This arrangement prevents mistakes, and obviates the necessity for any mental calculation of loose weights, &c. As the weights are never taken off the steelyard, they cannot be lost or mixed with the weights of other machines, or be placed on dirty substances, and thus they do not become heavier by being clogged with dirt. The firm claim that each machine they turn out is carefully tested and adjusted to its full capacity and guaranteed to be perfectly accurate on every part of the platform and not in the middle only. It is therefore quite immaterial, in weighing, on what part of the platform the goods to be weighed are placed.



FIG. 15. AUTOMATIC SLIDE REST. MESSRS C. E. LUGARD & CO., CHESTER.

When the machine is out of use, or being loaded or unloaded, wear and damage to the centres are entirely prevented by the relieving apparatus, which unhooks the steelyard, entirely disconnecting it from the working parts of the machine, at the same time lowering the platform on to solid supports, and the levers to the bottom of the box or frame, leaving the steelyard in a level position, by which arrangement the knife-edge centres are preserved from wear during the act of lifting the platform into a position for weighing and letting it down into a dormant state again. When the machine is out of gear, no centre in it can be affected by any weight placed on the platform, and thus, when fixed in a warehouse floor, any amount of traffic may be taken over it without the least injury to the working parts. The frames also are made with solid, close bottoms to exclude damp, and all the centres work in cups of oil. The machines may therefore be fixed in damp places without injury to them. The platforms are carried on a species of universal joint. They can thus swing freely in any direction without grinding or damaging the centres, or disturbing the levers or any of the underparts.

Messrs. The Stern Sonneborn Oil Company, Ltd., of 16, Finsbury Square, London, E.C., exhibit lubricating oils and greases in endless variety, and suitable for almost every requirement, as well as a new product known as "Screwol," which is a soluble oil for use as a lubricant when machining metal. This oil readily forms a soapy compound with water, which, it is claimed, as regards practical utility and efficiency, far exceeds any mixture of soap and water as hitherto used, and in this connection a practical demonstration is given on the stand on a lathe supplied by Messrs. Redman & Sons, of Halifax. The oil will mix with up to 95 per cent. of water, and this proportion is recommended for general use. It may also be used for machinery which is constantly in contact with water, such, for example, as that used in pumping, mining, and boring, where it prevents the formation of rust and minimises friction. Tests have, we understand, been carried out with mixtures of "Screwol" and water, and soap and water, in various proportions, steel and cast iron being immersed in them and the effects noted from time to time. Whatever the period of immersion, the cast iron retained far more of its natural lustre and suffered much less discoloration in the "Screwol" and water mixture. Similarly the steel showed little or no diminution of its brightness and the dark spots were comparatively few. Soap, on the contrary, produced entire discoloration of the iron, mingled with many dark spots, whilst the steel became much corroded, showing numerous large dark spots. Further, the loss of weight produced by the action of the oil and water was much less, varying, it is stated, from about one-half to one-sixth of that caused by soap and water.

Messrs. C. E. Lugard & Co., of Chester, show their now well-known "Vulkan" drive fitted to a "Stirk" planer; a model of a "Vulkan" clutch, 7ft. 3in. diam., weight 6¼ tons, as supplied to Messrs. Cochrane & Co., Middlesbrough, in February, 1910, capable of transmitting 1,000 h.p. at 75 revs.—the largest magnetic clutch in the world; a rapid automatic slide rest capable of turning up 26 pairs of standard railway wheels in nine hours; and the "Pillow" flexible coupling. This latter we have previously described.

Fig. 14 shows a section of the "Vulkan" reversing electromagnetic clutch. It consists, as will be seen, of a cast-steel shaft, drilled for lubrication, a disc armature, fixed to the shaft (1), and two electromagnetic bodies running loose on the shaft. Each magnetic body is fitted with an annular energising coil (2) wound for any convenient voltage, and a ventilating ring (3). The disc armature is fitted with a thrust ring (4), adjustable and renewable without dismantling.

Continuous current is supplied to one of the energising coils through the slip rings, and as soon as the circuit is closed the loose running magnetic body is held by magnetic attraction to the disc armature. The magnetic faces of the clutch are kept apart by the thrust ring leaving an air gap between them, any heat generated being thus dissipated by the ventilating ring. To reverse, the current is switched over from one energising coil to the other.

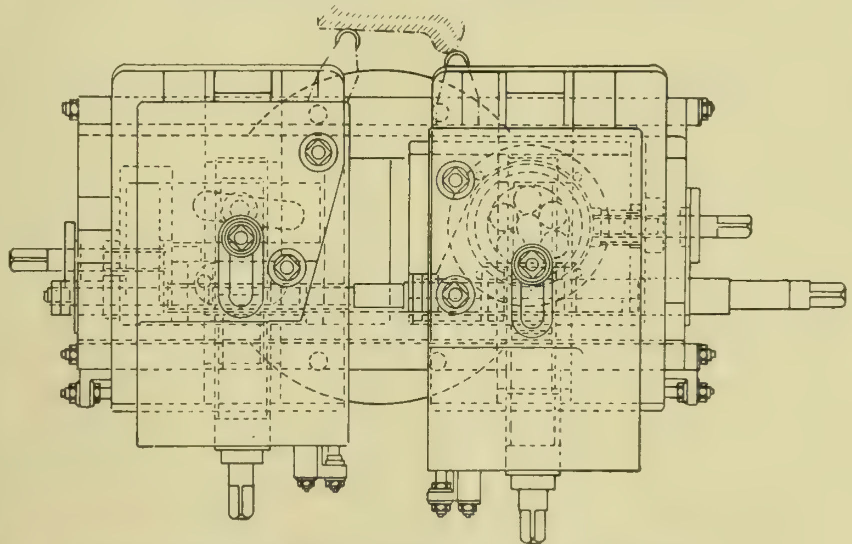


FIG. 16.—AUTOMATIC SLIDE REST. MESSRS. C. E. LUGARD & CO., CHESTER.

The advantages claimed for this drive are that no lubrication of the rubbing surfaces is necessary; that there is no loss of efficiency if lubricated accidentally; that it will engage or disengage without shock, is easily controlled, has small current consumption, and that it is simple and compact. When applied to planing machines, which may be old or new ones, no striking gear or shifting belts are necessary, and there is a constant speed for any length of stroke.

The automatic slide rest shown by Messrs. Lugard & Co. we have pleasure in illustrating in Figs. 15 and 16. This has been designed, as mentioned before, for profile turning work, usually requiring skill and close attention if the result is to be accurate. Automatic slide rests have been devised with an extended template, which gives an irregular feed, and fails to produce a correct shape of flange; with a template corresponding to the outline along which the guide is driven by gearing revolving on a curved rack; this increases the number of slides, and places the template too far from the work, so that the tool springs on heavy cuts, and owing to the shape of the rack teeth gives an uneven feed; and with a template along which the guide is driven by an apparatus which follows as far as possible the form, and as the profile roller must be driven during part of the cycles against the full pressure of the tool, the rest binds on the steep parts of the curve, and it is not always possible to turn back by hand. Any of the above systems may be used for light finishing cuts, but for heavy cuts on modern high-speed lathes they are quite unsuitable.

The template of the rapid patent automatic slide rest consists of an outer and inner closed curve of the same shape as the profile to be turned. Between these two curved surfaces two case-hardened rollers are placed, one being the driver and the other the driven, which are interspaced by two or more case-hardened friction rollers. The driver is fitted on to a pin fixed on the top of the worm-wheel drive, the driven is fitted on to a pin fixed below the slides of the rest, and the transmission between the two is made through the intermediate friction rollers. The size and shape of these rollers has been determined after a great number of experiments, with the result that no binding is possible at any part of the curve, and the tool can always be moved in either direction by hand without using the handle, and even on the heaviest cuts the movement is quite easy with the handle provided.

The rapid automatic slide rest, as will be seen, is fitted with two templates, one for the flange and one for the tread, both of which can be easily and quickly changed, and it will be noticed that two tools operate at one and the same time. To obtain the best results, however, a modern high-speed lathe should be fitted with two ordinary slide rests, each fitted with two tools, arranged as back rests, and used for turning the sides of the wheels. Also two rapid automatic rests arranged as front rests, and used for turning the flange and tread. Thus eight tools are working at once.

Fatal Crane Accident.—A plate inspector was killed in Messrs. Stewarts & Lloyds' Clydesdale Steelworks, Mossend, on the 15th inst. by a plate weighing 15cwt. falling upon him. The plate was suspended by a crane when the clutch slipped, and the heavy weight came upon the unfortunate man, fracturing his skull.

New Large Battle-ship laid down at Portsmouth.—The first keel plate of a new type of battle-ship, which is to be built in record time, was laid down at Portsmouth on Monday last. The vessel, we understand, is to be launched in the exceedingly short period of four months from the laying of the keel. To this end, an enormous quantity of building material is already alongside, ready for the workmen, who will be employed in day and night shifts. Although the usual secrecy is being observed as to the features of the vessel, it is understood that she will have a greater displacement and be somewhat longer than any other existing vessel.

The Effects of Deficiency of Oxygen on the Light of a Safety Lamp.—At a meeting of the South Staffordshire and Warwickshire Institute of Mining Engineers recently held at Birmingham a paper on this subject by Dr. J. S. Haldane and Dr. T. L. Llewellyn, was read. It stated that, roughly speaking, every diminution of 0·1 per cent. in the oxygen caused a diminution of 3·5 per cent. of the value of the light in pure air, or for every 17 per cent. of diminution in the value of the light in fresh air there was a diminution of about 0·029 per cent. in the oxygen. With the oxygen reduced to 19·0 per cent., the minimum percentage allowed by the Coal Mines Act for purposes of ordinary work, the light would be diminished by 70 per cent. under the conditions of the experiment.

SOME ASPECTS OF WIRE DRAWING.*

BY PERCY LONGMUIR, M.MET. (SHEFFIELD).

GOERENS, in his admirable paper on "The Influence of Cold-working on the Properties of Iron and Steel," touches on many aspects of value to wire-drawers. Perhaps one of the most important points developed is that of what may be termed "low" temperature annealing. For example, he states: † "A further deduction may be drawn in reference to the annealing temperature that is necessary for the annealing of cold-worked material. This is that the temperature of allotropic changes need not be reached for the establishment of the equilibrium and the dispersion of the cold-hardened condition. Heating at 520°—or 580°, according to the kind of material—for a short time suffices to restore the normal properties of the materials almost completely."

Three papers of considerable importance to the students of wire-drawing practice are: (1) "Iron and Steel Wire and the Development of its Manufacture," by J. P. Bedson, "Journal of the Iron and Steel Institute," 1893, No. II. (2) "Wire and Wire-drawing," by J. D. Brunton, "Journal of the West of Scotland Iron and Steel Institute," 1900. (3) "The Heat Treatment of Wire," by J. D. Brunton, "Journal of the Iron and Steel Institute," 1906, No. II.

These papers deal with points relating to the more practical side of wire-drawing. Thus Bedson, in 1893, drew attention to the importance of lubrication: ". . . the wire-drawer taking great care that, as the rod passes through the plate, plenty of tallow or other lubricant is applied to the rod at the point of admission to the conical hole of the plate, otherwise the piece would scrap and eventually 'pull the hole out,' and thus deform it from its original size." In this paper and the ensuing discussion the embrittling effect of acids on steels is evidenced.

Brunton, in his paper of 1900, describes the cleaning house as the very heart of a wire mill—". . . and unless every attention is paid to this portion, there will be endless trouble in the subsequent processes and tons of wire spoilt." Again, in his 1906 paper, Brunton uses the term "brittleness of pickling," and this aspect has been subsequently developed by Burgess, under the heading of the embrittling effect of acids.

In 1911 the present author‡ quoted a few results of this embrittling effect shown on rail steel rolled down to 5-gauge rod. The foregoing summary indicates that attention has been directed to three points: (1) Annealing temperatures, including physical condition of rod. (2) Lubrication. (3) Cleaning. In addition to these, the following factors may be instanced: (4) Rate of flow, including amount of reduction per draft. (5) Contour of hole. (6) Efficiency of the "coating" on the wire.

There are, of course, other conditions, but the six quoted are really fundamental to the wire-drawing industry. It is questionable whether any of these conditions have received serious attention from the industry except in isolated instances. Indeed, the industry as a whole is ruled by traditional empiricism rather than by exact knowledge. Further, the student of actual practice is confronted by real difficulties in the form of accumulated prejudice rather than recorded fact.

Regarding the subject as a whole, one of the chief features is the physical condition of the rod. If cold-working is to be effective, the rod must be uniform throughout its length. With the long lengths of to-day, perfect uniformity in the rod "as rolled" is impossible, and of necessity the finishing temperature of the back end differs materially from that of the front end. There is, therefore, a corresponding difference in the condition of the rod, and, generally speaking, it will be found gradually to increase in hardness from the beginning to the end of the coil. This difference between the ends may be comparatively light, but unless the rod is initially equalised throughout, its effect will be felt in the later stages of drawing. Various tests have been made, and Table I. is quoted as typical of a case in which special efforts were taken to ensure uniform conditions in rolling.

* Abstract of paper presented before the Iron and Steel Institute, October, 1912.
† "Journal of the Iron and Steel Institute," Carnegie Volume, 1911, p. 398.
‡ "Journal of the Iron and Steel Institute," 1911, No. 1, p. 163.

TABLE I.—*Approximate Length of Rod*, 1,154*ft*. *Analysis.*

	Per Cent.
Carbon	0·68
Silicon	0·20
Manganese	0·75
Sulphur	0·03
Phosphorus	0·03

Locality.	Beginning of Coil.		End of Coil.	
	Max. Stress. Tons per Square Inch.	Elongation per Cent. on 2 Inches.	Max. Stress. Tons per Square Inch.	Elongation per Cent. on 2 Inches.
4 feet from end...	47·2	16·5	50·1	14·5
5 ,, ,,	47·6	14·0	50·4	13·5
6 ,, ,,	47·2	15·5	50·0	14·5
7 ,, ,,	47·6	13·5	52·0	13·0
8 ,, ,,	49·1	14·0	50·7	13·5
9 ,, ,,	47·4	15·0	50·4	13·0
Mean...........	47·6	14·7	50·6	13·6

The difference between the back and front end is in this favourable case only 3 tons per square inch on the maximum stress. Slight as this difference may appear to be, it would, in the absence of a normalising process, have a very material effect on the "flow" of the wire during drawing.

Industrial "flow" demands equality of section, therefore the reduction in area effected by drawing through a plate must be uniformly consistent throughout the length of the wire. The general tendency is to put cold work on a hot rolled rod before any normalising has been effected, and in these cases the effect of cold working is such as to develop a habit which persists through later annealing stages. This habit may take the form of "non-sizing"—that is, pulling out the hole, or acute local brittleness. In either case the wire-drawer usually blames the steel, and, so far as the Yorkshire wire-drawing districts are concerned, the usual phrase is: "The composition has been altered."

Many cases have been investigated, and in not one instance has composition been found to be at fault. In all cases the steel, considered as steel only, has been found to be correct, but its manipulation has been wrong. One of the first studies in manipulation is that of obtaining physical uniformity throughout the length of the wire, and it is here that the least work has been done.

If the rod as hot rolled is not in a state of equilibrium, then cold work intensifies, and to some extent fixes, its condition, and later heat treatment does not necessarily remove a "fixed habit." The first care of the wire-drawer should therefore be that of effective normalisation, and this may be attained by patenting or annealing. In either case the process must have some relation to the thermal transformations of the steel in question.

A study of current wire-drawing practice reveals the fact that generally annealing operations have no relation to thermal transformations. Temperatures are rarely taken, and the only guide is empirical judgment. Over a variety of practice the range in temperature may be estimated to vary from 550° to 700° C. Both temperature and time decrease with the reduction of the wire in size. This would indicate that wire-drawers have to some extent intuitively recognised that only the effect of cold working has to be removed, and therefore Goerens' "low" temperature annealing has long been recognised in practice.

The effectiveness of this annealing is open to question, and not only is the "flow" less the lower the temperature, but further, the resulting hardness is greater. Advantage can be taken of this fact when working to a definite hardness value in either cold rolled strip or drawn wire. By suitable adjustment of annealing temperatures to cold work a given hardness can be obtained, to a certain extent, irrespective of the composition of the steel. This emphasizes the fact that if annealing temperatures are to be seriously studied, then a sharp line must be drawn between the first and the later annealings. The first annealing should relate solely to the condition of the hot-rolled rod, whilst later annealings have a relation to the stresses developed by cold-working.

Table II. gives the tensile values obtained from successive stages of cold-working. It will be noted that only one heat treatment is involved, and this is an initial one before cold work commences:—

TABLE II.—*Analysis.*

	Per Cent.
Carbon	0·67
Manganese	0·78
Silicon	0·126
Sulphur	0·027
Phosphorus	0·032

Condition.	Size in Inches.		Max. Stress. Tons per Square Inch.	Elongation Per Cent. on 2 Inches.	Reduction of Area Per Cent.
Rolled rod	0·365 × 0·228		48·00	15·0	39·75
Patented rod	,,	,,	49·00	12·5	16·7
Cleaned and blued...	,,	,,	50·16	10·8	20·4
	Reduction in				
	Width.	Thickness.			
Drawn—1st hole......	0·035	0·057	64·4	5·0	23·2
,, 2nd ,, ...	0·025	0·043	71·32	4·9	22·3
,, 3rd ,, ...	0·017	0·023	78·00	6·5	23·0
,, 4th ,, ...	0·013	0·019	85·18	4·0	20·0
,, 5th ,, ...	0·020	0·018	92·24	4·3	18·2
,, 6th ,, ...	0·006	0·008	98·21	4·9	20·0

In this case the total reduction involved in the six drawings is about 82 per cent., and the effect of this is shown in raising the maximum stress of the wire from 48 tons per square inch in the rod to 98 tons per square inch in the final product. Patenting temperature ranged from 900° to 950° C.

In this class of wire uniformly high patenting temperatures are essential, and the primary object is to obtain a perfectly normalised rod. With unequal or erratic patenting it is possible to obtain from one rod, when drawn down to final size, maximum stress values ranging from 80 to 120 tons per square inch. Ineffective or irregular patenting is responsible for many faults found later in the finished wire. In Table III. further results are given; these represent a patented wire of lower carbon content than those of Table II.:—

TABLE III.—*Analysis.*

	Per Cent.
Carbon	0·57
Manganese	0·73
Silicon	0·168
Sulphur	0·029
Phosphorus	0·029

Condition.	Size in Inches.	Max. Stress. Tons per Square Inch.	Elongation Per Cent. on 2 inches.
Patented rod........................	0·296	56·2	17·0
Drawn, 1st hole......................	0·257	65·2	5·0
,, 2nd hole	0·222	66·5	8·0
Finished, 3rd hole..................	0·184	77·9	6·5
Patented rod	0·262	56·2	15·0
Drawn, 1st hole......................	0·239	73·6	6·0
,, 2nd hole	0·192	78·8	6·0
Finished, 3rd hole	0·161	84·9	6·5

The effect of initial size in the case of treated and untreated rod is to some extent shown in Table IV.:—

TABLE IV.—*Analysis.*

	Per Cent.
Carbon	0·50
Manganese	0·90
Silicon	0·06
Sulphur	0·039
Phosphorus	0·051

Condition.	Rod as rolled. Maximum Stress. Tons per Square Inch.	Rod annealed at 700° C. Maximum Stress. Tons Per Square Inch.
4 G. Rod	44·5	37·5
Finished wire..................	64·0	55·0
3 G. rod	46·0	45·0
Finished wire..................	69·0	60·5
2 G. rod	45·5	45·3
Finished wire..................	73·5	63·0

Annealing applies to the rolled rod only, and during drawing no further heat treatment was applied. The effect of

initial size is shown to some extent, and also the difference in condition.

Tables III. and IV. represent experimental conditions; various studies have been made of "flow" whilst drawing under the conditions of commercial production. Of these, two examples may be quoted: thus Table V. embodies tensile results at various stages in the working down of a medium carbon steel. It will be noted that the first two holes drawn represent work on an untreated rod, and the maximum stress is raised to 81 tons per square inch. In later stages this value is not again reached. Each annealing stage represents a temperature range of 700° to 750° C.

It has been stated that cold work can be so adjusted as to give, within limits, hardness irrespective of composition. This is illustrated in Table VI., in which the results obtained from a rod of 1·04 per cent. carbon are given. This flat wire is purposely not overworked between the annealing stages, in that after drawing and rolling a fair amount of later work has to be put on the wire in order to bring it into its final marketable form. Hence, the wire is maintained in a soft condition as regards its carbon content, and the requisite hardness is obtained by oil tempering.

TABLE V.—*Analysis.*

	Per Cent.
Carbon	0·54
Manganese	1·07
Silicon	0·051
Sulphur (below)	0·060
Phosphorus	0·060

Gauge.		Reduction in Drawing. Inch.	Tensile.			Condition.
Before Drawing.	After Drawing.		Max. Stress. Tons per Square Inch.	Elong. per Cent. on 2 Inches.	Reduced Area per Cent.	
5	—	—	57·00	16·00	36·50	As rolled.
5		—	52·00	19·00	41·90	Cleaned and blued.
5	7	0·042	70·00	5·00	25·70	After drawing 1st hole.
7	9	0·029	81·20	5·50	23·70	After drawing 2nd hole.
9	—	—	34·25	47·85	69·40	After annealing.
9	—	—	34·25	47·85	69·12	Cleaned and blued.
9	11	0·033	53·10	16·40	58·82	After drawing 3rd hole.
11	13	0·023	61·25	11·70	52·30	After drawing 4th hole.
13	—	—	36·50	38·50	75·46	After annealing.
13	—	—	37·00	43·75	75·46	Cleaned and blued.
13	15 G.E.	0·022	54·50	11·70	55·26	After drawing 5th hole.
15 G.E.	17 G.	0·012	64·50	7·00	54·17	After drawing 6th hole.
17	—	—	38·00	37·50	79·50	After annealing.
17	—	—	37·50	39·00	79·50	Cleaned and blued.
17	18½	0·012	56·50	7·00	66·60	After drawing 7th hole.
18½	21¼	0·010	64·00	5·45	55·55	After drawing 8th hole.

Two entirely distinct types of steel were drawn down in successively small reductions. Both steels were annealed in the rod at 700° to 720° C., and then drawn down. Beyond this preliminary annealing no heat treatment was applied, and the results typify the effect of "flow" by light drafts. One steel contained:—

	Per Cent.
Carbon	0·10
Manganese	0·89
Silicon	0·06
Sulphur	0·103
Phosphorus	0·307

This steel was decidedly abnormal as regards its contents of sulphur and phosphorus, yet its "flow" was remarkably good. Commencing at roughly 5-gauge, it admitted of reduction to 23-gauge without any intermediate heat treatment. The maximum stress values rose from about 36 tons to 112 tons per square inch. Beyond 23-gauge the wire would not admit of further reduction.

The other steel was of the following analysis:—

	Per Cent.
Carbon	0·48
Manganese	0·87
Silicon	0·058
Sulphur	0·039
Phosphorus	0·050

In this case it was only possible to reduce down to 17-gauge, and the maximum stress rose from 43½ to 100 tons per square inch.

TABLE VI.—*Analysis.*

	Per Cent.
Carbon	1·04
Manganese	0·67

Gauge of Wire before Drawing.		Reduction in Drawing.		Tensile.			State of Wire in Process.
Breadth. Inch.	Thickness. Inch.	Breadth. Inch.	Thickness. Inch.	Max. Stress. Tons per Square Inch.	Elong. per Cent. on 2 Inches.	Reduced Area per Cent.	
0·260	0·142	—	—	65·64	9·80	35·97	As rolled.
0·260	0·142	—	—	41·00	18·50	51·35	After annealing 1st time.
0·260	0·142	—	—	39·85	18·00	51·35	After cleaning and blueing.
0·260	0·142	0·026	0·037	56·60	10·00	7·70	After drawing 1st hole.
0·234	0·113	—	—	36·89	17·00	53·85	After annealing 2nd time.
0·234	0·113	—	—	36·89	18·75	35·85	After cleaning and blueing.
0·234	0·113	0·036	0·011	52·46	9·00	5·00	After drawing 2nd hole.
0·198	0·102	—	—	34·01	27·00	56·42	After annealing 3rd time.
0·198	0·102	—	—	33·01	25·00	58·53	After cleaning and blueing.
0·198	0·102	0·030	0·025	48·47	12·50	43·07	After drawing 3rd hole.
0·168	0·077	—		35·00	40·60	51·13	After annealing 4th time.
0·168	0·077	—	—	35·00	40·60	51·13	After cleaning and blueing.
0·168	0·077	0·012	0·006	41·00	16·00	43·65	After drawing 4th hole.
		Incr. in Breadth.		*Effect of Wire-rolling.*			
0·156	0·071	—	—	35·00	40·50	52·27	As annealed 5th time.
0·156	0·071	—	—	35·00	40·50	52·27	Cleaned and blued.
0·156	0·071	0·016	0·033	55·00	10·90	30·70	After 1st rolling.
0·172	0·038	—	—	38·05	39·00	47·69	As annealed 6th time.
0·172	0·038	—	—	38·05	36·00	30·76	Cleaned and blued.
0·172	0·038	0·020	0·014	57·06	7·00	19·88	After 2nd rolling.
0·192	0·024	—	—	39·50	31·75	50·00	As annealed 7th time.
0·192	0·024	—	—	38·00	31·75	50·00	Cleaned and blued.
0·192	0·024	0·012	0·006	42·20	12·50	24·34	After 3rd rolling.

In neither case did the increase in tensile strength possess an exact ratio to the amount of "flow." The steadying effect of the elongation after fracture was, however, significant.

The foregoing notes are presented with the one object of arousing interest in, and possibly discussion of, wire-drawing problems. Contact with these problems leads to the conclusion that dogmatism is impossible, but the field for study and research is exceedingly wide. The author's most cordial thanks are due to Mr. P. Leather for his ready assistance in conducting tests and experiments.

Two Men Electrocuted.—An accident occurred at the Devonshire Works of the Staveley Coal and Iron Company on the 17th inst., when two workmen received fatal shocks from an electric cable. Considerable use is made of electricity at the works, both for lighting and power, and overhead cables run from the generating house to various parts of the company's extensive premises. The two men were engaged in painting, and one of them was at work on an electric standard, when, it is presumed, he accidentally touched a high-tension cable carrying over 6,500 volts, and was unable to release himself. The other man, who was at work elsewhere, promptly went to his mate's assistance, but as soon as he touched his body he himself received a charge of electricity and was rendered helpless. An alarm was given and the current cut off, when it was found that the two men were terribly injured and expired shortly after admission to the hospital.

THE VAUCLAIN DRILL.*

BY A. C. VAUCLAIN AND HENRY V. WILLE.

SPEAKING generally, there can be no better definition of economical drilling than "rapid drilling"—the saving of time. The fact that a drill will cut at some phenomenal speed or will consume such and such an amount of power means nothing so far as productive capacity is concerned. The object in view is the removal of chips. The productive possibilities of any metal-cutting tool are limited by its stress and heat-resisting capacities. The temperature at which it

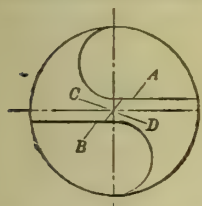


FIG. 1.—COMMON TYPE OF TWIST DRILL.

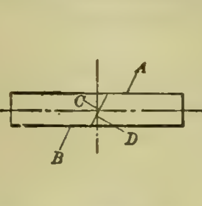


FIG. 2.—COMMON TYPE OF FLAT DRILL.

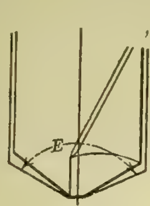


FIG. 3. SHOWING INCLUDED ANGLE OF CUTTING EDGES OF 118°.

will continue to operate successfully depends upon the excellence of material and manufacture, but the rapidity of heat generation and the stresses set up in the tool depend upon the design of the tool and the selection of feeds and speeds. With a given excellence of material and manufacture, the strength of the tool must depend upon the extent and disposition of the section. The size of the drill is necessarily limited by the size of the hole to be drilled. The section of the drill has a lesser area than that of the hole, since space must be provided for the discharge of chips from the hole. The design of the drill should therefore be that which will give it the maximum of strength and strength conservation.

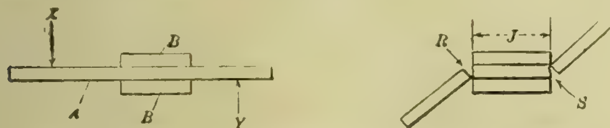


FIG. 4.—ILLUSTRATING SPLITTING ACTIONS BY MEANS OF WIRE HELD IN VISE.

Cutting stress is practically independent of the cutting speed and with a given feed is proportional to the lip angle of the cutting edge. The cutting stress does not increase as rapidly as the feed. The rapidity with which cutting heat is generated depends upon the cutting speed, the depth of feed and the lip angle of the cutting edge. Since both the stress and heat are influenced by the keenness of the cutting edge, it is desirable that the lip angle be as small as possible. But it must be blunt enough to carry off the heat and to support the chip pressure, which falls more or less back of the actual



FIG. 5.—DIAGRAM ILLUSTRATING PRINCIPLE OF VAUCLAIN DRILL.

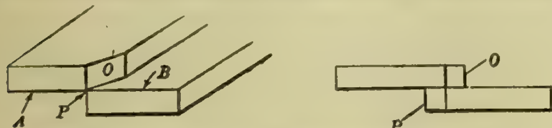


FIG. 6.—CENTRAL EDGES OF FIG. 5 SHOWN BEVELLED.

cutting edge, according to the depth of feed. Since the chip is torn, not cut from the work, rupture between work and chip precedes the actual cutting edge. The heavier the feed, the farther back from the cutting edge will its pressure fall upon the tool. Under ideal conditions, the torsional capacity of the drill should be its limit of cutting strength. This does not obtain in the present commonly used types of drill, and they break down very considerably below their torsional strength. Why this is so will be explained later in detail.

The feed remaining constant, the horse-power consumption will be proportional to the speed. This is true both of the power consumed by the machine and that consumed in cutting. The speed remaining constant, the power consumed in cutting does not increase as rapidly as the feed, and the power consumed by the machine remains constant for all feeds. From this, it will be seen that the most economical method of chip production is by giving preference to the feeds, rather than the speeds. Power, time, and drills will be saved thereby.

Figs. 1 and 2 illustrate the section scheme of drills now commonly used. While there are many modifications of these, the figures suffice to illustrate their common characteristic, which is that the cutting edges A and B pass to one side of the axis of motion of the drill instead of through the axis. In this respect there is no difference between Figs. 1 and 2. It will be seen that in this scheme the drill has four distinct edges, A, B, C, and D, and that the usual name given to it of "two-lip" drill is not correctly applied.

Referring to Fig. 3, it is customary for the included angle E to be of 118° and the cutting edges C and D, Figs. 1 and 2, therefore have an unfavourable lip angle. These edges constitute what is commonly called the chisel point and their cutting resistance is very great. The cutting edges A and B cut more freely than the cutting edges C and D and a tendency to longitudinal fracture of the drill is set up thereby. This is the cause of the splitting of drills. In explanation of this splitting tendency, Fig. 4 represents a section of brittle wire A held in vise jaws B. If sufficient pressure is applied, as indicated by arrows X and Y, the wire will break at R and S, due to the resistance of the vise and to the forces X and Y tending to revolve it about its axis.

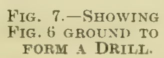


FIG. 7.—SHOWING FIG. 6 GROUND TO FORM A DRILL.



FIG. 8.—SHOWING APPEARANCE OF DRILL WHEN TWISTED.

Those portions of the wire not within the vise jaws represent, in the drill, the cutting edges A and B, Fig. 1, free cutting, due to their favourable lip angle. That portion of the wire held within the jaws represents the cutting edges C and D, or the chisel point, embedded in the work and having to overcome a high cutting resistance due to the unfavourable cutting lip angle of these edges. Under very heavy feeds, these two edges tend to stand still, while edges A and B continue to cut, with the result that the drill is fractured in a manner similar to the breaking of the wire in Fig. 4. In the

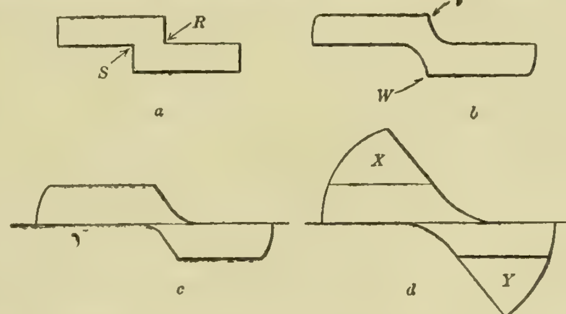


FIG. 9.—SUCCESSIVE SECTIONS SHOWING DEVELOPMENT OF BAR OF FIG. 5 INTO FORM ADAPTED FOR VAUCLAIN DRILL.

drill the width of the vise jaws becomes infinitesimal and the fractures R and S coincide and constitute the longitudinal splitting of the drill.

In the commonly used types of drills there are but two methods of reducing the chisel point, viz., by thinning the drill at its centre, or by pointing. By the former method the resistance to longitudinal splitting becomes lowered and by the latter method the cutting edges lose their support at and near the centre of the drill.

By the foregoing it will be seen that the feed possibilities of the ordinary types of drills are not very great. Either the drill will split or its cutting edges will break under heavy feeds, long before its torsional capacity is reached. Summed up, the disadvantages of this type of drill are as follows: (*a*) Its weakness. (*b*) The unfavourable cutting lip angles of the chisel point create a tendency to longitudinal splitting of the drills. (*c*) If the chisel point is reduced by central thinning of the drill, the resistance to longitudinal splitting is lowered. (*d*) If the chisel point is reduced by pointing, the cutting edges are deprived of their essential support at and near the centre of the drill. (*e*) Essential central thickness and cutting edge support are obtained only in connection with a considerable chisel point. (*f*) The tendency to longitudinal

* Abstract of paper read before the American Society of Mechanical Engineers.

splitting is increased by any increase in the extent of the chisel point. (*g*) The resistance to penetration due to the chisel point is very great and is increased by any increase in the extent of the chisel point. (*h*) It is not adapted to heavy feeds, and must therefore be used under the conditions of moderate feeds and high speeds, the least economical method of chip production. (*i*) There are four cutting edges, two of which do not pass through the axis of motion, hence the aggregate length of the cutting edges is excessive. This is productive of greater torque, hence of power consumption.

The Vauclain drill is a "heavy feed" drill adapted to the most economical method of metal cutting and of great strength, due to its design. In order better to describe the drill, the section scheme will first be explained diagrammatically and the development of the actual section will then be illustrated. In Fig. 5 is shown a bar comprising two flat bars overlapping and integrally connected, as indicated. By bevelling, as shown at O and P, Fig. 6, the edges A and B are made to meet at the axis of the bar. Since these bevelled surfaces are at an angle with the axis the integral connection between the two flat bars remains unbroken. Fig. 7 indicates how the end of the bar would appear when ground to form a drill and Fig. 8 how it would appear if twisted.

FIG. 10.—DIAGRAM SHOWING EXACT FORM OF CONSTRUCTION OF DRILL.
Circle A = Circumference of drill; Diam. of circle B = $\frac{3}{16}$ diameter of drill; diam. of circle C = $\frac{3}{16}$ diameter of drill; S = $\frac{3}{32}$ of diameter of drill; T = $\frac{3}{16}$ of diameter of drill; XY indicate cutting edges.

Fig. 9a again shows the section or end view of the bar in its original form. Introducing fillets at R and S gives the form shown in Fig. 9b, and removing the corners W and V modifies it as in Fig. 9c. In Fig. 9d, by adding areas X and Y to the section, its torsional value is increased. Fig. 10 shows the exact section profile and in Fig. 11 is reproduced a photograph of three of these drills. By examination of the illustrations it will be seen that the chisel point is eliminated without central thinning of the drill and without weakening the cutting edges.

FIG. 11.—EXAMPLES OF THE VAUCLAIN DRILL.

The improved design of this drill has brought about the following important features: (*a*) Essential central thickness is secured. (*b*) Cutting edges are properly supported at all points. (*c*) Chisel point, with its unfavourable lip angles, is eliminated without weakening drill or cutting edges. (*d*) Cutting edges pass through axis of motion. (*e*) There are only two cutting edges. (*f*) Aggregate length of cutting edges is reduced to minimum.

As a result of these features the following advantages are secured: (*g*) Increased strength and reduced liability to splitting. (*h*) It is adapted to heavy feeds, the most economical method of cutting metal. (*i*) Productive capacity is increased. (*j*) Horse-power consumption per unit of metal removed is reduced. (*k*) Life of drill is increased and frequency of grinding is less. (*l*) Distress in machine is less and resistance to penetration is reduced. (*m*) Better holes are produced and afterwork of reaming is less.

AUTOGENOUS WELDING OF ALUMINIUM-COPPER AND ITS ALLOYS.*

BY DR. F. CARNEVALI.

IN a previous paper, presented to the October (1911) meeting of the Iron and Steel Institute, dealing with a series of investigations concerning the oxy-acetylene autogenous welding of iron and steel, I pointed out that the enormous development which this process has undergone within the last decade in regard to wrought iron, steel, and cast iron has led to its extension to other metals of common use, such as copper with its chief alloys and aluminium. The empirical manner, however, in which the process has been applied in this new field, and the lack of systematic and complete researches, have conduced to results so diverse, often imaginary and discordant, as to permit of the formation of contradictory opinions, and thereby to arrest its possible further development. With the view of eliminating these uncertainties and contradictions in regard to the new process, and with the view also of increasing the knowledge thereof and of obtaining data of practical utility, I have undertaken, as complementary to the series of investigations carried out on iron and steel, the study of the oxy-acetylene welding of various metals (iron excepted) largely used in modern industry, particularly copper and its principal alloys and aluminium.

The investigations which I have conducted were planned on the same method as those already published in regard to iron and steel, and were subject to analogous criteria. I have endeavoured to comply with all the conditions essential for obtaining favourable results, and to overcome as far as might be the difficulties which most frequently attend the autogenous welding of metals. At the same time, I have tried to reproduce as closely as possible the conditions which can be obtained in practice.

I propose to divide this group of researches on the oxy-acetylene autogenous welding of metals largely used in practice, other than iron, into two groups, as follows: (1) Oxy-acetylene autogenous welding of copper and its principal alloys; (2) oxy-acetylene autogenous welding of aluminium.

Copper.—A first series of experiments was carried out with pure copper, containing 99·9 per cent. of the metal, the welding metal being copper wire of equal purity, supplemented in certain cases by a small quantity of phosphorus, in order to obviate possible oxidation of the metal during the process of welding. The samples were cut off round wire-drawn rods, measuring 35 millimetres ($1\frac{3}{8}$in.) in diameter; each sample was sawn half through, and the edges were thrust apart in the form of a V at an angle of about 45°. After welding, some of the samples were cooled in air, while others were subjected to various thermic and dynamic processes; and, being thus prepared for mechanical experimentation, were so treated as to undergo a notable diminution of their original diameter (in order to ascertain the success of the welding operation), care being always taken that the weld should be in the centre of the sample. Before and after the mechanical tests, from each sample a portion was taken from the zone of welding, and a portion from the immediately neighbouring zone, for purposes of microscopic examination. In Tables I. and II., a summary is given of the experiments and observations made in this first series of researches. A microscopic study of the samples was directed to the zone of welding, including the structure of the portion added for the weld, also the original structure of the metal and its structure in the intermediate stage. This research exhibits clearly the change induced by the process of welding in the mechanical properties of the metal, as also the profound alteration of its structure, as may be seen by comparing Figs. 1 and 2 (enlarged 80 diameters; etching by an aqueous 10 per cent. solution of nitric acid).

The first figure exhibits the structure of the original heated metal (sample 1, Table I.), and the second the structure of the welded zone (sample 2, Table I.). In this last, the great development which the crystals of copper have undergone will be noted, a development due to the high temperature attained by the fused metal in process of welding. The suboxide formed during this process, and dissolved within the metal, may be observed in the form of little globules disseminated within the crystals. In those samples where, on the contrary, the metal used for the weld consisted of phosphorised copper, the suboxide is practically

* Abstract of paper read before the Institute of Metals, September, 1912.

eliminated; but, coincidently with that elimination, very slight modifications in the mechanical properties of the metal are observable. This shows that the small quantities of suboxide disseminated in the zone of welding have but little effect in the way of modifying the properties of the metal. This difference of structure between the original metal and the metal added in welding may be easily noted by direct observation, without even the aid of the microscope. A close examination of a section of the above-mentioned example 2 (Table I.) cut from the piece subjected to the torsional test, near the zone of rupture and etched by an aqueous 50 per cent. solution of nitric acid, showed that the metal was not deformed by the strain to which it was subjected; that the rupture did not take place in the fused and welded zone, but in a neighbouring zone, following the margin of the weld-surface in the original metal that had not undergone fusion. A more minute investigation, while showing continuity between the welding material and the original metal, also revealed in this intermediate zone the presence of innumerable tiny vesicular cavities. They were recognisable even by direct observation of the fractured surface of the sample, imparting to it a peculiar loose granulation apparently due to the presence of oxide. A micrograph was obtained showing precisely the characteristic texture of this intermediate zone. At the bottom, the fused portion of the original meta and the welding material was compact and non-vesicular; on the other hand, cavities were numerous in the zone of metal which had not been subjected to fusion. The same observation may be extended to all the welded samples of copper in which fracture has taken place. Examination of the fractured surfaces of pieces of welded copper which had been subjected to the torsional and shock tests showed that the rupture of the welded samples had taken place along the margin of the chamfer. The explanation of this apparently curious fact is easy enough, if we consider under what conditions the welding of copper takes place. The great thermal conductivity of copper, for one thing, is well known; this conductivity, indeed, is so great as to make the process of welding big masses extremely difficult, if not impossible. We know also how easily that metal absorbs gases at high temperatures. In the oxy-acetylene process of welding, the tongue of the flame is rich in hydrogen and in carbon monoxide, products of combustion which are easily absorbed by the metal during the heating up that precedes fusion, prolonged as it is by the high thermal conductivity of the metal.

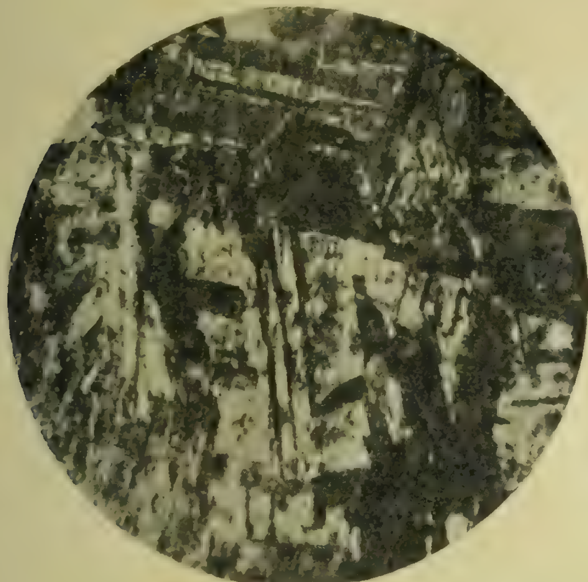


FIG. 1.



FIG. 2.

When the internal surface of the parts which are to be welded begins to melt, then the metal used for the weld is applied thereto, its fusion taking place with extreme rapidity, the period of heating being very briefer, as the material used consists of fine-drawn wire. Cooling and solidification also ensue quickly; while,

TABLE I.

No. of Sample.*	Measurements of Sample in Millimetres.	Thermal and Mechanical Treatment.	Average Ultimate Stress. Kgs. per Square Mm.	Average Elongation. per cent.	Average Contracted Diameter in Mm.	Average Hardness. Brinell,† 500 Kgs. Ball 10 Mm. Diameter.	Remarks.
1	Diameter= 15 ..	Reheated	23·0	43·4	—	0·38	Not welded.
2	Useful length=150 Do.	Cooled in air after welding	10·5	2·6	—	44·5 in the weld	Welded with pure copper; rupture in the weld; fracture coarsely and irregularly granular; vacuoles (small) present.
3	Do.	Do.	12·3	3·1	—	43·0 do.	Welded with phosphorised copper; rupture in the weld; medium-grained fracture.
4	Do.	Reheated	11·3	4·8	—	36·0 do.	Do. do.
5	Diameter= 12 ..	Not repeated	24·0	40·0	7·3	54·0	Not welded.
6	Useful length= 100 Do.	As Sample 2	12·9	2·0	11·8	35·0 in the weld	Welded with pure copper; rupture in the weld; coarsely granular fracture.
7	Do.	As Sample 4	13·5	4·5	10·3	34·5 do.	Do. do.
8	Do.	Hammered and reheated after welding.	14·2	3·4	11·2	36·0 do.	Do., medium-grained fracture.
9	Do.	Do.	13·1	2·8	11·6	40·0 do.	Welded with phosphorised copper; rupture in the weld; medium-grained fracture.

* Two samples, prepared and treated in the same way, correspond to each number.
† The Brinell tests were carried out on samples other than those subjected to the torsional tests.

TABLE III.—*Shock Tests with the Charpy Apparatus.**

No. of Sample.	Initial Dimensions of Sample.	Thermal Treatment.	Indicated Angle.	Breaking Test. Kgr. Mm.	Mean Chemical Analysis. Of the Metal. per cent.	Mean Chemical Analysis. Of the Welded Zone. per cent.	Remarks.
A1	Rods. diameter= 40 millimetres.	Rough fusion	128°	4·646	Cu.= 94·2 Sn =5·7	—	Not welded.
A2	Do.	Reheated	119°	6·698	—	—	Do.
A3	Do.	Cooled in air after welding	141°	2·112	—	Cu= 94·89	Welded; medium-grained fracture, with small vacuoles.
A4	Do.	Reheated after welding....	132°	3·807	—	—	Welded; medium-grained fracture, with vacuoles.
B1	Do.	Reheated	134°	3·407	Cu= 87·9 Sn= 11·01 Zn= 1·03	—	Not welded.
B2	Do.	Cooled in air after welding	140°	2·286	-	Cu= 90·2 .... Sn= 9·01 .... Zn= 0·8	Welded; finely granular fracture, with numerous vacuoles.
B3	Do.	Reheated after welding....	139°	2·464	—	—	Do. do.
C1	Do.	Reheated	136°	3·019	Cu= 87·1 Sn= 9·3 Pb= 3·48	Cu= 89·7 .... Pb= 2·9	Not welded.
C2	Do.	Cooled in air after welding	145°	1·457	—	--	Welded; finely granular fracture, with numerous vacuoles.
C3	Do.	Reheated after welding....	139°	2·464	—	—	Do. do.

* See Table II.

from the mass of metal which heated up more slowly, that is, from the original surface of the chamfer, the gases absorbed in great quantity during the period of heating which preceded the actual welding are eliminated coincidently with the fall of temperature.

But the elimination of these gases is not complete, as the main mass of the added welding material is at this time quite solidified, and so their occlusion determines the formation of small vacuoles along the original surfaces of the welded parts, that is, along the surfaces of chamfer. These surfaces, pitted with vacuoles and considerably oxidised (despite the precautions

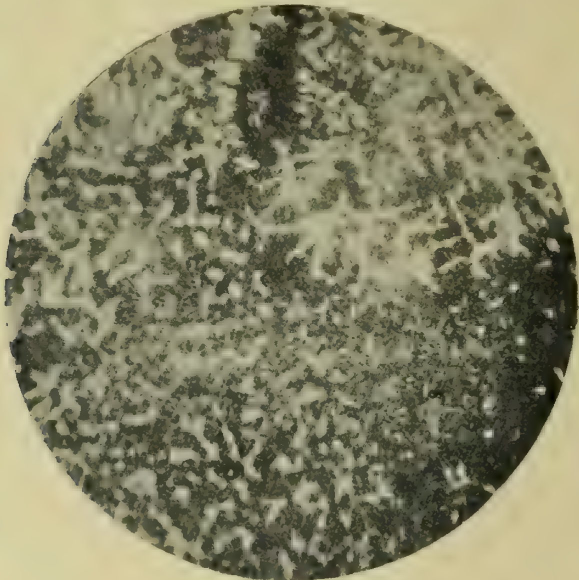


FIG. 3.

observed during the process of welding), constitute a plane of weakness when the metal is subjected to strains and stresses, and it is consequently along them that fracture takes place.

The inevitable existence in the zone of welding of a weak surface, of low resisting power, being admitted, it will be easily understood how, when carrying out mechanical processes on the weld, as, for example, by hammering, which are intended to assimilate the structure of the welded portion to the original structure of the metal, we obtain a very low efficiency factor, if not one equivalent to zero. This will be noted on referring to the data set forth in Table I., and for this reason I have not thought it opportune to insist on these mechanical processes in the course of the various series of experiments.

Of greater efficiency, on the other hand, are thermal processes such as reheating for about half an hour to 750° or 800° C., to which several samples were subjected after welding, as may be gathered from the results set forth in Tables I. and II. A favourable effect on the mechanical properties of the welded metal might be expected from this treatment, as it tends to relieve the strain often set up within the metal during the process of welding, and to restore homogeneity to its structure. We may note in this respect the results obtained from the Brinell tests of hardness (see Table I).

TABLE II.—*Shock Tests with the Charpy Apparatus on Prismatic Rods,* $10 \times 10 \times 60$ *millimetres, with semi-circular notch half-way down,* 2 *millimetres deep* (*distance of supports,* 40 *millimetres).*

Bob (weight) = 22·45 kilogrammes.
h= 1·3363 metre.

No. of Sample.	Initial Dimens'ns of the Sample.	Thermal Treatment.	Angle of the Indicat'r	Breaking Test. Kgs. Mm	Remarks.
1	Rods, 35 mm. in diam.	—	110°	8·936	Not welded.
2	Do.	Reheated ..	109°	9·194	Not welded.
3	Do.	Cooled in air after welding.	139°	2·464	Welded with phosphorised copper; medium-grained fracture.
4	Do.	Do.	134°	3·407	Welded with pure copper; coarsely granular fracture.
5	Do.	Reheated after welding.	132°	3·807	Do. do.

Bronze.—A second series of analogous investigations was carried out on three ordinary types of bronze, which, for the sake of brevity, are here designated as A, B, and C. Their chemical composition was as follows :—

	A.	B.	C.
	Per cent.	Per cent.	Per cent.
Copper	94·2	87·9	87·1
Tin	5·7	11·01	9·3
Zinc	—	1·53	—
Lead	—	—	3·48

The metal was in the form of rods, measuring 25 millimetres (1in.) in diameter, cast in moulds of well-dried earth, so as to ensure homogeneity of the alloy. As welding material, very thin rods of bronze of exactly similar composition were used. The experiments were conducted in the same manner as the first series. But we must at once observe that in every case,

despite all the precautions taken, innumerable vesicular cavities were formed in the zone of welding over the entire surface of the weld. For this reason I have thought it advisable to limit investigation to tests of fragility and to microscopic examination: the former were carried out, assuredly not in the expectation of

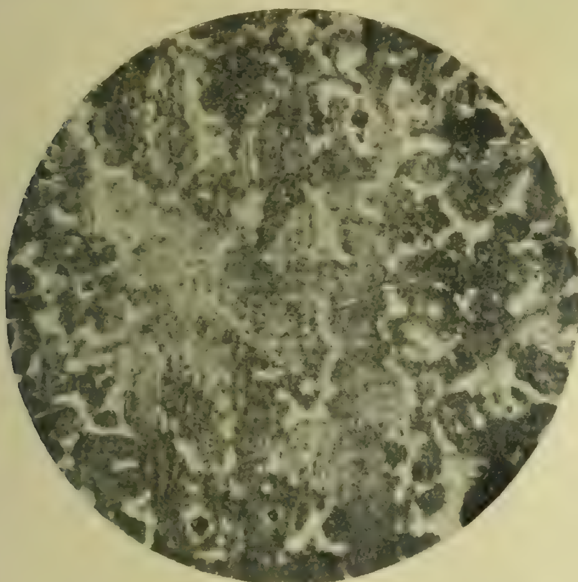


FIG. 4.

determining with precision the mechanical properties of the metal (more or less modified in process of welding), but in order to ascertain, at all events approximately, how far its resisting power had diminished. In the accompanying Table III. are set forth the results of the experiments and the observations to which they gave rise.



FIG. 5.

Microscopic examination of the various samples has confirmed the experimental results. The great heat to which the metal is subjected, and the sudden variations of temperature which occur within it during the process of welding and in the course of the subsequent cooling, each play their part in modifying profoundly the structure of the metal in the zone of welding. High temperatures, facilitating the oxidation of the fused metal by means of the action of the oxygen of the atmosphere, determine, in the first place, the oxidation of those constitutive elements of the alloy which have most affinity for oxygen —as, for instance, tin, zinc, and lead. This oxidation reveals itself in the decreased proportion of those elements which in part are volatilised and in part pass into the slag in the form of oxides; also in the formation of bubbles or vesicles, arising from the partial reduction of these very oxides by the excess of metal (the metallic mass) present; also in the lowering of the mechanical properties of the zone of welding caused by the innumerable vacuoles set up within it, and accentuated by the diffusion of tin dioxide (SnO_2) in the mass of the alloy, partly in the shape of acicular inclusions.

Moreover, the high temperature attained in the course of the process of welding, with alloys of low tin content (alloy A), in which really a single constituent is present—*a* "mixed crystals" of copper and tin—determines, as we have seen in the case of pure copper, a commencement of ignition of the metal, with the consequent formation of big granules.

Finally, the rapid variations of temperature during the process of welding, determine—in the case of bronzes of higher tin content, wherein two constituents are present, namely, the α and β mixed crystals of copper and tin—an irregular and very conspicuous sub-division of these constituents, imparting to the metal a heterogeneous structure. This will be seen on referring to Fig. 3 (enlarged 80 diameters, etched with a 4 per cent. hydrochloric acid solution of ferric chloride), which illustrates the structure of the zone of welding of sample B 2 (Table III.). Here we see clearly the minutely irregular distribution of the "solid solution" β, which is made the more manifest by comparison with Fig. 4, representing the well-developed homogeneous structure of the original reheated metal (sample B 1, Table III.).

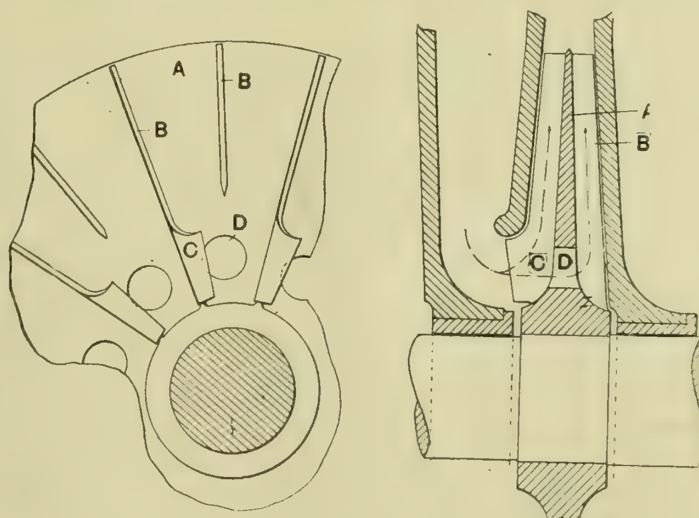
The localisation of the surface of fracture in the samples of welded copper to the margin of the chamfer is again observed in the case of the zone of welding of bronzes. The consequent structural modification, partly analogous to that undergone by copper, is illustrated in Fig. 5 (usual enlargement, usual etching) which represents the passage-zone between the fused welding material and the original surface of sample C 2 (Table III.). Towards the top of this figure we notice numerous vacuoles, while these are absent in the fine-textured welding material, made up of small *insulæ* of lead and of "solid solution" β, immersed in a sea of "solid solution" α.

Admitting all that precedes, we may reasonably expect that an appropriate reheating of the welded portion will prove even more efficacious than in the case of copper, because, in addition to relieving the internal strains of the metal set up by the process of welding, it tends to restore to it an improved homogeneity of structure.

(To be continued.)

IMPELLERS FOR TURBO-COMPRESSORS OR CENTRIFUGAL PUMPS.

THE accompanying illustrations show a construction of impeller for turbo-compressors or centrifugal pumps, the invention of the Warwick Machinery Company (1908), Ltd., 83, Cannon Street, London, E.C., and Mr. R. H. Collingham. The impeller is in the shape of a disc having blades or vanes secured to or formed integral with the disc on both sides. A single entrance is provided on one side for the fluid to pass to the impeller and apertures are formed in the disc to allow the fluid to pass to the side remote from the entrance. The blades



IMPELLER FOR TURBO-COMPRESSORS OR CENTRIFUGAL PUMPS.

are formed so that some at least extend to the nave or boss of the disc, the longer vanes on the inlet side being bent so that the edges meet the incoming fluid with as little shock as possible. The area of the apertures through the disc is made sufficient to allow the incoming fluid to flow in as unrestricted

a manner as possible to the side of the impeller remote from the inlet so that during operation a portion of the fluid drawn into the casing will pass through the apertures. If the number and lengths of the blades or vanes of both sides of the disc are equal, the pressure head generated along both sides of the impeller will be equal and there will be no end thrust due to unbalanced forces, consequently no thrust bearings or other balancing devices are required to take up the unbalanced thrust or produce an equal and opposite thrust. The position of the disc or web may be varied from the centre so that the widths of the vanes on either side will differ and the amounts of fluid passing through on each side will be unequal. The actual position of the web is fixed by theoretical and practical considerations in each case.

Referring to the illustrations, A represents the central web or disc, upon both sides of which are blades or vanes B either secured to or formed integral with the web. Some of these blades as shown extend to the nave or boss of the disc. The incoming fluid enters the impeller through the aperture C and the inner edges of these blades on the entering side of the impeller are curved so as to meet the incoming fluid with as little shock as possible. In order to allow some of the fluid to pass to the other side of the impeller apertures D are formed through the disc A. This construction permits of a considerable reduction in the over-all dimensions of turbo pumps or compressors as compared with double inlet impellers, especially when a plurality of impellers are used in series with each other. It is also very well adapted for dealing with gases and liquids at high temperatures or for such fluids as contain tar or other impurities, as small clearances between the impeller and casing are unnecessary.

MISCELLANEA.

Boiler Explosion at Birmingham.—The formal investigation ordered by the Board of Trade to be held into the boiler explosion which occurred at the premises of the late firm of Messrs. W. H. Butcher & Co., 30, Princip Street, Birmingham, is fixed for hearing in the Council House, Birmingham, on Wednesday, the 30th inst., at 11 a.m.

The Institution of Mechanical Engineers.—The first monthly general meeting of the coming session will be held on Friday, the 25th inst., at 8 p.m., when papers on "Characteristic Dynamical Diagrams for the Motion of a Train during the Accelerating and Retarding Periods," by Prof. W. E. Dalby, and "Theory and Experiment in the Flow of Steam through Nozzles," by Prof. J. B. Henderson, D.Sc., of Greenwich, will be read.

"Electrit" Grinding Wheels.—A new abrasive, termed "Electrit," is made from pure aluminium oxide by melting it in an electric furnace at a temperature of about 3,000° C. (5,400° Fah.). Its specific gravity is less than that of emery and corundum, but its hardness is, it is stated, considerably higher, about 9¼ on the 10° hardness scale. The grain of "electrit" is almost amorphous, resistant under pressure and shock, tough and not brittle. "Electrit" grinding wheels are bound ceramically, are proof against moisture and acids, and can be used either for wet or dry grinding.

West of Scotland Iron and Steel Institute.—The 21st session of the West of Scotland Iron and Steel Institute opened on Friday last, when Mr. Walter Dixon delivered his presidential address. During the session papers will be read by Mr. F. Rogers (Sheffield) on the "Resistance of Steel to Shock," Prof. Coker (London) on "Colour Photography of Interval Stress in Bodies of Engineering Form," Prof. Turner (Birmingham) on "Puddling," Mr. C. O. Bannister (London) on "Regeneration and Recuperation of Waste Heat," besides papers by Profs. Campion and Longbottom (Royal Technical College, Glasgow), and by Mr. F. W. Matthewman (Sheffield).

The Smoke Nuisance.—The Manchester Branch of the Smoke Abatement League of Great Britain sent a deputation to the Trading Profits Committee of the Manchester Corporation on the 16th inst. in order to submit proposals which would encourage the use of gas and electricity, and thus reduce the smoke nuisance in the city. Prof. Chapman said that it was generally agreed by economists that it was right for the community to make profits in certain directions in order to subsidise their work, but they must choose the right articles to tax. Gas and electricity were pre-eminently the wrong articles, as their taxation meant the pollution of the atmosphere. Gas cooking was now about at the margin of profitableness. A small reduction in price might mean a big increase in use, and would therefore pay the community well. The smoke in Manchester was responsible for driving people out of Manchester, and for the rateable value not increasing as fast as it should. The committee promised to give the matter due consideration.

Dynamometer Car for Japan.—Prof. E. C. Schmidt, of the University of Illinois, has been commissioned by the Japanese Government to design a railway dynamometer car for the Imperial Government Railways. The car, which will be constructed under the supervision of Prof. Schmidt, and is expected to be delivered next spring, is to be 48ft. long, 8ft. 6in. wide, adapted at present for 3ft. 6in. gauge, with provision for changing later to 4ft. 8½in. gauge. It is to be equipped with vacuum brakes, and the design of such details as drawbar, buffers, journal boxes, &c., is to conform to Japanese railway standards. The car is to be of the hydraulic dynamometer type such as has been developed at the University of Illinois. The recording apparatus will permit the measurement of tractive efforts up to 80,000lbs., and will provide also for the measurement of speed, time, distance, vibration, buffer thrust, &c. The car and the apparatus will be designed for a maximum speed of 85 miles per hour. Axle generator and storage battery will be provided to supply current for operating the recording apparatus and for lighting purposes.

Battery-driven Train. — The first railroad train operated by storage batteries equipped with multiple unit control recently ran a trial trip over the Long Island Railroad, when the distance of 25 miles was covered in 57 minutes, and the return journey in 53 minutes. The train is equipped with Edison storage batteries. It has been built for the United Railways of Cuba and is intended for service on a branch from Havana about 100 miles long, on which a steam locomotive drawing one coach is now employed. It consists of three cars, each equipped with four 200-volt motors and 216-cell Edison batteries. The important feature is that more than one car is operated by a single controller according to the multiple unit control system. The battery has a capacity of 60 to 100 miles with seven hours' charging, but by giving it short intermediate charges during the day's work a higher efficiency and a greater mileage can be secured. The power consumed by the train on its demonstration run was about 4 kw. per train mile.

Institution of Engineers and Shipbuilders in Scotland. — The syllabus for the 56th session of the Institution of Engineers and Shipbuilders in Scotland has just been issued. The session was opened on October 22nd by a meeting in the Rankine Hall of the Institution, 39, Elmbank Crescent, Glasgow. At this meeting the president—Mr. E. Hall-Brown, now general manager of the Middlesbrough works of Messrs. Richardsons, Westgarth, & Co., delivered his inaugural address. During the session a number of important papers will be read, among those arranged being: "Development in Auxiliary Units Between Exhaust Pipe and Boiler," by Mr. William Weir; "Recent Developments in Wireless Telegraphy," by Mr. J. Erskine-Murray, D.Sc.; "Subdivision of Ships," by Mr. J. Bruhn, D.Sc., chief surveyor to the Norske Veritas; "Boat-lowering Appliances," by Mr. Axel Welin; "Oil-carrying Steamers," by Mr. J. Montgomerie, B.Sc.; "Injuries to Steel Subsequent to Its Manufacture," by Mr. Cecil H. Desch, D.Sc., Ph.D.; "Oil Fuel for Power Purposes," by Prof. Thomas Gray, D.Sc., Ph.D., and Prof. A. L. Mellanby, D.Sc.; and "Moulding Machinery for Foundry Purposes," by Mr. Thomas Macdonald.

Cleaning Evaporator Tubes.—At present, says L. W. Thurlow in the "International Sugar Journal," there is much lack of system in the selection of suitable means for removing scale from the evaporator tubes of multiple-effect apparatus used in cane-sugar factories. When the scale consists chiefly

of calcium oxalate, sulphate, and carbonate, it is of little use applying sodium hydrate (caustic soda), as the surface of the incrustation remains quite hard. Hydrochloric acid alone has but little effect, as this only slightly disintegrates the surface. The most effective means is to treat first with a boiling solution of sodium carbonate, and then with dilute hydrochloric acid. The sodium carbonate should be a 3 per cent. solution, and the hydrochloric acid 1 per cent. Fill the evaporator with a 3 per cent. solution of sodium carbonate and raise the temperature to the boiling point, without a vacuum, as a high temperature is desirable. Every half-hour titrate a sample of the evaporator's contents against standard acid, and continue the boiling until the figures are constant; the transformation from oxalate and sulphate into carbonate is then complete. Now run off the liquid in the evaporator, fill it up again with water, and then add the 1 per cent. solution of hydrochloric acid. Heat to boiling and again titrate against standard alkali. The reaction is generally complete within one hour.

The Corrugated Ship.—At the Royal United Service Institution, Whitehall, on the 16th inst., Captain G. S. Macilwaine, R.N., read a paper on the corrugated ship. The author said the corrugated ship followed a number of digressions from the normal, some of them more or less ephemeral, and was, he believed, destined to a more prolonged life than some of its predecessors. The claims put forward for the ship were that she was stronger than the plain ship, that she was steadier at sea, that her stability was greater, that vibration was much reduced, and though her tonnage remained the same, her capacity for cargo, both bulk and weight, had increased, that her construction facilitated the handling of cargo in her holds, that her cost of construction was not greater and in time would probably be less than that of the plain ship, that she was handier and answered the helm more quickly, and that she was faster for the same horse-power, or more economical in fuel for the same speed. He had no hesitation in saying that of the two the corrugated ship was much less vulnerable than her plain sister, that she would stand collisions of all sorts better, and in case of injury would be more easily repaired, and that she was in every way much stronger than the plain ship. The lecturer gave particulars of the "Monitoria" and the "Hyltonia," two corrugated vessels, bearing out his contentions. He explained that the space between the corrugations seemed to act as a conduit pipe supplying the screw, which in its turn seemed almost to play the part of a pump, drawing a solid mass of water along the ship's side in which to work. The corrugated principle was applicable to vessels of all sorts, from the yacht to the most heavily armoured battle-ship. If he were right, the birth of the corrugated idea meant nothing short of a revolution in the building of ships, whether pleasure, life-saving, mercantile, or Imperial.

Flotation of Ores.—At a meeting of the Institution of Mining and Metallurgy held in London on the 18th inst., Mr. J. W. Ashcroft read a paper dealing with "The Flotation Process" as applied to the concentration of copper ore at some mines in New South Wales. The former mill using water washing gave a concentrate carrying about 20 per cent. of copper with an extraction of 74 per cent., but since smelting was abandoned and the ore shipped the high cost of transport necessitated better working. The oil flotation process has been proved successful in raising the extraction to 86 per cent., and the tenor of the concentrate to 22·6 per cent. of copper. The ore, after crushing and sizing, is mixed with a very small proportion of eucalyptus oil, which is manufactured cheaply in the district, and the froth which is produced buoys away most of the copper minerals, these being recovered by settlement in a tank. The cost of installation was shown to be quite 25 per cent. less than the former mill, and the cost of running the flotation process was no more when calculated on a basis of the higher grade of product got. The process also possesses the advantage over other similar processes in that no acid is required, and the solutions do not require to be heated. Mr. Ashcroft described improvements made to effect greater saving by regulating the ore feed and the thickness of the pulp, accurate control of the oil supply and the speed of the stirrers also being important.

INDUSTRIAL AND TRADE NOTES.

Fatalities from Industrial Accidents.—Exclusive of seamen, the number of workpeople reported as killed in the course of their employment during September was 210. During the nine months ended September, the total number of workpeople reported as killed in the course of their employment (exclusive of seamen) was 2,173. The number of seamen killed in the same period was 1,740.

Yates & Thom, Ltd.—This engineering firm reports a profit for the year ended August 10th of £16,172, making, with £8,529 brought forward, a total of £24,701. Debenture interest absorbs £4,040, depreciation £5,000, and preference interest £6,215. The directors recommend a dividend on the ordinary shares of 2½ per cent. for the year, absorbing £2,825, leaving £6,621 to be carried forward.

The New Light-armoured Cruisers.—It is understood that five of the new light-armoured cruisers are to have Parsons turbines and three Brown-Curtis turbines. The Parsons ships will be Beardmore's three and Vickers's two. Fairfield's ship is to have Brown-Curtis turbines, and so are the two ships which are to be built at Chatham and Pembroke respectively. The contractors for the machinery of the dockyard ships are the Thames Ironworks Company.

Oil Engines for a Naval Tank Ship.—The Admiralty have, we are informed, placed contracts for marine oil engines greater in power than any yet put in hand for the British naval service. Messrs. Vickers, Ltd., have been entrusted with the work, and the new engines, which are of the Vickers design, are to be fitted in a vessel 460ft. long with oil tanks to carry 8,000 tons, for the supply of fuel oil for warships at sea. There will be two engines in the ship driving twin screws, and each of these will have eight cylinders. Messrs. Vickers will also build the vessel.

The Tees and Armour-plate Making.—A scheme is, we learn, under consideration for establishing armour-plate works in South Durham, or on the Yorkshire bank of the Tees. The making of armour-plate is at present confined to a few firms, and Sheffield is the most important centre of the trade. The new undertaking is intended to compete with Sheffield for a share of the work. Armour plate making is a highly specialised industry, and the laying down of the necessary plant is a very costly matter. The profits, however, are reputed to be large, and up to now the prices have been the more easily regulated because of the small number of firms in the business.

Federation of Iron and Steel Workers.—The ambitious scheme promoted some time ago for the federation of all trade unions in the iron and steel trades has received a set-back by the hostility of the British steel smelters, perhaps the most important union in the group. The result of the ballot gives a majority of 18,989 out of a total membership of 27,885 against the scheme. Only a few months ago the steel smelters declared heavily in favour of an amalgamation of all unions in the steel trade, but the scheme fell through owing to the opposition of the smaller unions. Ultimately, however, a compromise was reached by which two small unions were absorbed by the steel smelters.

Furness, Withy, & Co., Ltd.—In a circular issued a few days ago to shareholders in Furness, Withy, & Co., Ltd., the directors state that they find, after further consideration of the proposals for enlarging the capital, that the special reasons making "the early adoption of that course desirable have disappeared, since the increased profits accruing under existing trade conditions will enable the directors to provide for the payment of the additional properties recently acquired. Applying the surplus profits in this manner they regard as preferable to increasing the share capital." The board propose in future to pay quarterly dividends on the ordinary shares of 2½ per cent., free of income-tax, making 10 per cent. per annum, the arrangement to take effect on 31st inst., when an interim dividend of 5 per cent. will be paid for the two quarterly periods ending on that date.

Motor Barge.—The United Alkali Company, Ltd., who are large users of barges, decided a little while ago to experiment with a Thornycroft set. The boat in which this is fitted, the "E. K. Muspratt," is a ketch 84ft. long and 21ft. 6in. beam, with a cargo carrying capacity of 200 tons, and is now engaged in trading on the Mersey and various ports around the Lancashire coast. The engine has four cylinders, 6in. bore by 8in. stroke, driving a propeller at 350 revs. per minute, and is placed aft of the cargo hold, so that the cargo capacity is not affected. The fuel is paraffin. On a run of over 400 miles the average fuel consumption proved to be ·47 pint per brake horse-power per hour. The longest continuous run the vessel has yet made was of approximately 12 hours' duration, and with a cargo of 163 tons she attained a speed of 7½ knots with the tide. On her trials a mean speed of 5½ knots was obtained.

Accident Prevention.—In a recent paper on "Education in Accident Prevention," Mr. M. W. Mix, the president of the Dodge Manufacturing Company, said that in order to bring the matter of safety directly to the employés of his company, the management prepared a plan of education and competition between departments and their foremen, in the form of a percentage score board. The starting point is 1,000. Each division is penalised according to its accidents, minor accidents of less than one day's absence not being considered. The foremen of all of the divisions scoring 1,000, or those holding the first three places below 1,000, receive prizes of personal interest each month. The foreman scoring the largest number of first monthly prizes for one year receives a special prize at the end of the year. All divisions holding a percentage for the year of 1,000, or the highest annual percentage, receive two days' extra pay.

The Utilisation of Peat.—The Peat, Coke, and Oil Syndicate has been formed, with offices at Doncaster, to manufacture from peat foundry coke for steel smelting. The company claims to have perfected a new process for the utilisation of peat from the extensive peat moors around Doncaster and district, of which there are thousands of acres varying in depth from 4ft. to 10ft., and containing millions of tons of fuel and by-products. For some time experiments have been made with peat to prove its commercial value as a fuel, with the result that this company is now about to commence the manufacture from peat of a foundry coke for steel smelting, its special features being the low percentages of sulphur and ash—viz., 0·04 sulphur and 4·70 ash. Exhaustive tests have been made to warrant the company's erection of a plant to manufacture the coke for steel smelting and for use in suction gas plants, instead of anthracite coal. It is understood that a site has been secured for the works, with siding accommodation communicating direct with the peat moors.

The Boilermakers' Society.—The report of the Boilermakers' Society for the month of September states that the ballot which took place during the month on the question of admitting to membership the iron and steel shipbuilders employed in royal dockyards resulted in the rejection of the proposal by a large majority. The members of the society are being asked to vote at the November meetings for or against the federation of Liverpool shipwrights with the Boilermakers' Society. The arrangement which has been agreed to by the Liverpool Shipwrights' Society is that the shipwrights should make quarterly payments equal to 1d. per week per member, and that dispute benefits should be paid by the Boilermakers' Society at the rate of 8s. per week for eight weeks, subject to the sanction of the Joint Committee. If the arrangement is accepted by the boilermakers the agreement will remain in force for two years.

Employment in the Engineering Trades.—The employment returns of the Board of Trade for September show that the state of the labour market continued good, and was slightly better than a month ago. It showed a considerable improvement on a year ago, when it had not quite recovered from the effects of the disputes in the railway and other transport trades. The upward movement in wages continued. Compared with a month ago, there was some improvement in the coal mining, pig-iron, iron and steel, and engineering trades. Employment continued good in shipbuilding, and very good in tinplate manufacture. Compared with a year ago nearly all industries showed an improvement, which was most marked in the pig-iron, iron and steel, engineering, and shipbuilding trades. In the 383 trade unions, with a net membership of 877,811, making returns, 18,785 (or 2·1 per cent.) were returned as unemployed at the end of September, 1912, compared with 2·2 per cent. at the end of August, 1912, and 2·9 per cent. at the end of September, 1911. The changes in rates of wages taking effect in September were all increases, and amounted to £15,400 per week on the wages of 260,000 workpeople.

Electric Steel-smelting on Tyneside.—Steel-melting by electricity is to be adopted throughout in some new steelworks to be erected on the Tyneside by the Stobie Steel Company, of Sheffield. They will be the first big steelworks in Great Britain solely engaged in the electrical manufacture of tool steels, alloy steels, and other material. Not only the melting, but the further processes will all be carried out by electricity. Such an important project would undoubtedly have been carried out in Sheffield had not the charges for current been much more favourable on the North-east Coast. At first the installations will consist of a 15-ton three phase steel-melting furnace, a five-ton two-phase furnace for special steels, and a 3 cwt. alloy-melting furnace. They have been designed and built by Mr. Victor Stobie, who has made a special study of electric steel-melting. Experiments have been carried out for two years, and the present scheme is the outcome. A two-ton Stobie electric steel-melting furnace is shortly to be built for a Sheffield steelworks, and a 15-ton furnace is also projected for a steelworks in the North.

Canadian Iron and Steel Production in 1911.—The American Iron and Steel Association has recently published statistics relating to the production of steel ingots and of rolled iron and steel in Canada during the past year. The production of all kinds of steel ingots and castings in Canada in 1911 amounted to 790,871 gross tons, against 741,924 tons in 1910, an increase of 48,917 tons, or nearly 6·6 per cent. The production of Bessemer steel amounted to 189,797 tons in 1911, against 199,570 tons, and open hearth steel to 601,074 tons, against 542,354 tons. Of the total of open-hearth steel in 1911, 581,222 tons were ingots and 19,582 tons castings, against 524,191 tons of ingots and 18,163 tons of castings. All the open-hearth ingots were made by the basic process. The following table gives the production of various rolled products in the past three years:—

	1909.	1910.	1911.
Rails	344,830	366,465	360,547
Structural shapes and wire rods	74,136	80,993	76,617
Plates and sheets	36,241	26,642	14,833
Nail plate, bars, &c.	207,534	265,711	323,427
Total	662,741	739,811	775,424

The total production of forged iron and steel by rolling-mills and steelworks in Canada in 1911 amounted to about 18,832 tons, of which about 787 tons were iron and about 18,045 tons steel. In 1911 there were 27 works in six provinces which made steel ingots or castings or rolled iron or steel into finished forms, against 24 works in six provinces in 1910.

British Trade with Russia.—Figures contained in a Consular report just issued showing the imports into Moscow for the last five years from the four chief countries reveal the fact that Germany, France, and the United States have made great advances, while British imports have remained almost stationary. Certain branches of industry, says the British Consul, which once were practically British monopolies are now being exploited by foreign competitors. This is especially the case with spinning machinery, which at one time was almost entirely in the hands of British firms, partly because these firms led the way in this particular industry and partly because the managers of the numerous mills were nearly all Englishmen. Of late, however, other continental firms have entered into the market. They supply cheaper machinery, and aided by their trade banks can give longer credit than British firms are either able or willing to give. As, too, the number of British mill managers is decreasing, the report says, it is evident that although British supremacy in this line is not likely to be threatened, British firms will no longer enjoy the monopoly which once was theirs. To meet competition in all lines of manufactures the British agent considers the following are essential: Knowledge of local conditions, commercial travellers with a knowledge of Russian and catalogues in Russian with prices in Russian money, and ability to give credit. "British firms," he concludes, "cannot compete with foreign firms which are backed by their own trade banks, and until the United Kingdom establishes local banks in Russia and falls into line in this respect with other nations, British firms will always be at a serious disadvantage as far as the Russian market is concerned."

Wages in the Coal Trade.—A conference of the employers and workmen's representatives on the Coal Conciliation Board for the Federated area was held in London on Monday last, to further consider the application of the miners for an advance of 5 per cent. in wages. The following resolution was unanimously adopted: "(1) That the Conciliation Board be continued until the 31st day of March, 1915, determinable thereafter by a three months' notice on either side, with a minimum of 50 per cent. above the 1888 rate, and a maximum of 65 per cent. The procedure regulations of the present Board to apply. (2) That an advance of 5 per cent. in wages be paid to all underground workmen and those on the pit banks and screens manipulating the coal, by putting on the reduction of 5 per cent. made as from the first making-up day after the 20th of March, 1909, such advance to commence as from the third making-up day in October instant. (3) That the above advance be applied as regards piece and day wage men either upon the basis rate of 1888 or on the list rate, as has been the case hitherto, and where workmen are paid by contract and not earning the minimum rate fixed by the joint district board for the district there shall be paid to the workmen and those employed by them an addition to the minimum 5 per cent. on the 1888 rate so long as wages remain at 55 per cent. on the standard rate of 1888. In the event of a reduction of wages the above addition is to be subject to such reduction." This decision means that about 400,000 men employed in the coal mines of North Wales and England, excepting Northumberland and Durham, will receive 1s. per week increase, the sum involved being about £1,000,000 per annum.

Dick, Kerr, & Co., Ltd.—At the ordinary general meeting of shareholders of Dick, Kerr, & Co., Ltd., held a few days ago, the Chairman said it would be seen that the company had had a poor

year—indeed, the poorest year since the foundation of the business. Last year the directors indulged in an extremely moderate forecast, saying that should their hopes be fulfilled the prospects of a satisfactory result were encouraging. The prospects were encouraging at that time. The contracts entered into during the last five years had been taken in the face of great competition, and as much of the company's work was necessarily accepted a long time before it could be executed, a considerable number of contracts finished last year were, in fact, taken when such competition was at its keenest. In the immediate past the railway and coal strikes affected more particularly their manufacturing business at Preston. The net result in this department was that with the works order-book at the maximum their net production during the 12 months under review was, with the exception of one year, the minimum since they entered the field 10 years ago. The same remarks in respect to strikes applied to the contracting department. The contracts the company had in hand for this year they hoped would be remunerative. The order book was healthy, the Preston works being fuller than they had ever been of the class of manufacture best suited to it. In conclusion, he remarked that whilst the directors were disappointed in the result of the year's trading, they were convinced that there were many grounds for hope that the result revealed by the profit and loss account was one such as only came occasionally within the experience of any trading concern, and to that concern in particular. There never was a time in its history when its organisation was more complete or when its reputation to produce the best article stood higher.

Liabilities in Machinery Contracts.—The "Law Report" for October gives particulars of a case of which note should be made by all makers and purchasers of engineering machinery, as it has an important bearing on the question of damages in the event of disputes respecting the failure of machinery to comply with specification. The litigation in question, which has been dragging on for years, arose between the British Westinghouse Company and the Underground Electric Railway of London. The former sought payment from the latter for certain turbines they had supplied, but which failed to satisfy the specified conditions of economy. The railway company accepted the machines, but reserved their right to claim damages for breach of contract. Subsequently, to avoid the continuous loss of economy, they pulled out the defective machines and replaced them with Parsons turbines, and it appeared that if they had not done this the accumulated loss would have been greater than the price paid for the Parsons machines. Their loss, in fact, had they adhered to the Westinghouse machines for their normal life, would have been the difference between the actual running and the specified running over this term of years. When the case was put to an arbitrator he found that the railway company were entitled to recover the costs of providing the Parsons machines, and the Court of Appeal, to whom the case was subsequently referred, supported this decision, although the Parsons machines at the time of replacement were so superior that it would have paid the railway company to have inserted them even if the Westinghouse machines had in the first instance worked in accordance with the contract. Lord Justice Buckley illustrated the principle involved as follows: "If," he said, "a man who has taken a third class ticket from London to the North by one of the great companies is, by the negligence of that company, damaged by their breach of contract to convey him, and he, to reduce the damages, goes to another of the great companies, and takes a ticket by the next train on that line, and is thus enabled to reach his destination by the contract time, but cannot travel by that train unless he takes a first class ticket, his damages may well be the whole of the sum he has to pay for that ticket, although the result is that he has enjoyed a greater luxury of travel."

The Features of a Year's Shipbuilding.—Lloyd's Register of British and Foreign Shipping has just issued a report of the society's operations during the year 1911-12. It shows that at the end of June last 10,455 merchant vessels, registering about 21¾ million tons gross, held classes assigned by the committee of Lloyd's Register. Details of these show that 6,494 were British, of 13,283,681 tonnage, and 3,951 vessels belonged to foreign countries, comprising 3,271 steamers, of 7,365,904 tonnage. During the year classes were assigned by the committee to 681 new vessels, with registered gross tonnage of 1,468,166. Of this total about 68½ per cent. were built for the United Kingdom and about 31½ per cent. for the British Colonies and foreign countries. Compared with the preceding 12 months, the present return indicates an increase of 369,690 tons. The success of the first vessels fitted with engines of the Diesel type had already led to a very considerable increase in the construction of such vessels, especially in Holland and Germany. The development had been watched by the society's chief engineer surveyor, who had made a special study of internal combustion engines. It was felt, however, that the time had hardly arrived for the provision of rules on the subject. At the present time there were being built under the supervision of Lloyd's register Diesel engines for 34 vessels, 23 of which were of tonnages ranging from 2,000 to 10,000. The demand for new steamers intended for carrying oil in bulk, which last year was unusually brisk, had enormously increased. Since July 1st, 1911, 16 vessels (of 66,911 tons) intended to be used for this purpose had been assigned the society's classification, whilst there were now preparing and in course of construction at home and abroad 87 vessels, registering 479,000 tons, the plans for which have been approved by the committee. Ten of the vessels are 525ft. in length and of about 10,000 tons gross, these vessels being larger than any yet constructed for carrying oil in bulk. There was a great development in the use of oil fuel instead of coal. At the present time oil fuel bunkers were being constructed in 45 oil carrying vessels, whilst complete oil burning installations are to be fitted in 35 of the former and in nine of the latter. In the society's register book there are now 1,392 vessels fitted with wireless telegraphic installations, as compared with 1,013 at this date last year, and 630 fitted with submarine signalling apparatus, as compared with 566 last year.

Regulation of Wages in the Iron Trade.—The Industrial Council met in London on the 15th inst., Sir Thomas Ratcliffe Ellis presiding in the absence of Sir George Askwith, the chairman. Mr. William Thackeray, representing the Ironmasters' Association of the North of England, stated that for the purpose of fixing wages there was the sliding scale of 1889 and there was also the Arbitration Board, with a Standing Referee for settling disputes about employment as well as dealing with wages questions. There had been very few difficulties in the way of carrying out the decisions of the referee. He could not suggest any method better than the present one, but he did not think the organisation they at present possessed should receive statutory sanction or be made compulsory. Their present method covered works not in the union, and they had found the moral force in the management sufficient for settling disputes between employers and employed. All the ironworkers in the works contributed to the Arbitration Board. Mr. William Hawdon, on behalf of the Cleveland Ironmasters' Association, which represents pig iron, said that in 1897 a sliding scale was resolved upon to regulate wages, so that they might be adjusted according to the selling price of the material produced. In addition to the agreement as to wages there was another referring to the general conditions of labour. In the wages agreement there was a clause to the effect that any dispute should be referred to arbitration, and it was an understood thing that the same course would be taken in the event of any difference as to conditions of work. In the last 20 years there had been only two or three stoppages. If the committee failed to agree there was an agreement to refer to an umpire, and that was the arrangement he thought should be adopted. Their opinion was that the Trades Disputes Act should be altered or amended, for while it gave power to trade unions to negotiate collectively with the employers for an increase or reduction of wages, trade unions were legally absolved from responsibility for their action and damage done by individual members in breaking such agreements. He thought if they made a bargain with the union and they gave a certain order to the men the union ought to be responsible.

Education for Workmen.—In these days of high technical training and a continuous and pressing demand for more and more education for workmen, it requires some courage to utter so heterodox a statement as that made by Mr. Walter Dixon in the course of his presidential address at the West of Scotland Iron and Steel Institute, and yet Mr. Dixon is not alone among thoughtful men in believing that many of the current ideas of elementary education call for serious amendment. Much that is taught is of little practical value, and tends only to generate in imperfectly trained minds a sense of envy and disappointment. Mr. Walter Dixon said that enquiries made amongst those who had collectively the control of about 200,000 men in the iron and steel and allied industries showed it was the unanimous opinion that any book-learning outside the rudiments of the "three R's" was outside the requirements of the avocation of 90 per cent. to 95 per cent. of the usual manual workers. In other words, the work which these men were called upon to do, the labour which they had to perform in their daily avocation, would be as efficiently, as successfully, and as expeditiously performed if the men had no school education whatever outside and beyond "the three R's." Of the remaining 5 per cent. to 10 per cent., amongst whom were to be found the chargemen, foremen, and other leaders, most of these would attain to the leading positions in which they found themselves, through and by their own initiative, if three-quarters of the existing aids to learning were abolished, and that the plethora of educational facilities did not raise more than about 1 per cent. or 2 per cent. from the worker to the overseer stage. Incidentally he mentioned, without comment, a further widespread opinion that of the 90 per cent. to 95 per cent., not only would the work be done equally well and efficiently

were the workmen devoid of their present so-called "education," but it would be done more expeditiously and more satisfactorily, inasmuch as there would be less unreasonable restlessness, and less unreasonable discontent, the inevitable result and the danger of a universal "little knowledge" causing the men to be a constant and easy natural prey of those who had the little more, though equally inadequate, knowledge. The further unanimous opinion was that leaders, foremen, and overseers were in an overwhelming degree born, not made, and therefore that all forced school education beyond that already indicated—at least, all forced technical education—was for the majority whose lives must be devoted to manual labour not necessary—indeed, perhaps harmful.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Fire-tube boilers. Pielock. 15352.
Superheaters. Woodroffe. 19214.
Carburetters for internal-combustion engines. Gottmann. 19333.
Central buffer and draw gear for railway vehicles. Spencer. 19516.
Steam regenerative accumulators. Morison, and Contraflo Condenser and Kinetic Air Pump Company. 21197.
Rock drills. Knapp. 21257.
Propelling of vessels by means of steam and internal combustion engines. Thompson. 21299.
Steam generators. Turnbull, Davis, & Turnbull. 21338.
Air or gas compressors. Williams. 21347.
Machines for boring coal. Buckley & Smith. 21433.
Combination tool. Ironside. 21523.
Construction of smelting and fusing furnaces. Govan. 21588.
Apparatus for spraying liquid fuel. Polliak & Howson. 21681.
Sleeve-valve internal combustion engine. De Richelle. 21810.
Fireboxes for locomotive boilers. Sawyer & Newton. 21886.
Process and apparatus for manufacturing sectional iron. Weber. 21895.
Two-stroke cycle internal combustion engines. Ling Bevington. 22722.
Fluid-pressure regulating valves. Lake. 23007 and 23018.
Valveless internal-combustion engines. Lemperiere 23133.
Tool-holders for grinding machines. Lumsden. 23605.
Gas generators. Nickles. 24169.
Chain grate stokers. Rosenthal & Davy. 24336.
Friction clutches and brakes. Scarborough. 24469.
Locking-nut. Theobald. 26289.
Metallic packing for piston rods, &c. Griffiths. 27080.
Lubricating apparatus. Senkoff. 28142.
Gas purifiers. Milbourne & Bell. 28153.
Pouring gates for moulds. Mills & Joyce. 29348.

1912.

Steam superheaters for locomotive engines. Ferguson Superheaters, Ltd., and Ferguson. 1361.
Valves for internal-combustion engines. Beach. 2938.
Wooden belt pulleys. Wottle. 3947.
Spring coupling for shafts. Robert Bosch. 4598.
Vacuum breaking devices used in connection with exhaust steam condensers. Amor. 5001.
Method of treating cast-metal ingots. Russell. 5519.
Duplex piston engines. Levahn Motor Company A/S. 5959.
Pattern for foundry mouldings. Pipher. 6744.
Steering gear for marine vessels. Vigo. 8233.
Machines for planing and shaping metals. Dowding. 8281.
Carburetters for internal-combustion engines. Fielding. 9457.
Driving belt or chain. Price. 9606.
Mechanical stokers. Babcock & Wilcox, Ltd. 9693.
Automatic couplings for railway vehicles. Coles. 9728.
Exhaust silencers for internal-combustion engines. Clarke. 12647.
Shaft bearing. Bell. 13344.
Piston packings for hydraulic machines and engines. Heindl. 13595.
Lubricators for piston rods. Palomo y Goitiandia. 13600.
Metal beams or girders. Nowell & Nicholas. 13653.
Apparatus for smoke prevention and fuel economising in steam generators. Rothwell. 13724.
Rotary engine. Scrivener. 14116.
Reversing gear for engines. Koenemann. 14591.
Nut lock. Panalle. 15475.
Propelling means applicable for use with aeronautical machines, marine vessels, and road vehicles. Porter. 15735.

ELECTRICAL, 1911.

Electric furnaces. Queneau. 19305.
Method of electrically bonding rails. Vedovelli. 21720.
Telephone instruments. Derriman. 21812 and 21814.
Telephone systems. Derriman. 21815.
Vapour electric apparatus. Hewitt. 21827.
Electric incandescent lamps. Gast. 22779.
Electric lamps. Fulper. 22925.
Photometric apparatus for indicating and measuring changes in electrical pressure. Dow. 23931.
Wireless telegraphy. Gardner. 25278.

1912.

Electric frequency-indicating instruments. British Thomson-Houston Company. 628.
Trolleys or overhead collectors for electrically-driven vehicles. Francq & Francq. 7772.
Arc lamps. Schaffer & Heimann. 8140.
Apparatus for winding incandescent electric lamp filaments on their supports. Soc. Française d'Incandescence par le Gas (System Auer). 10092.
Plug connections for electrical work. Warner. 17151.

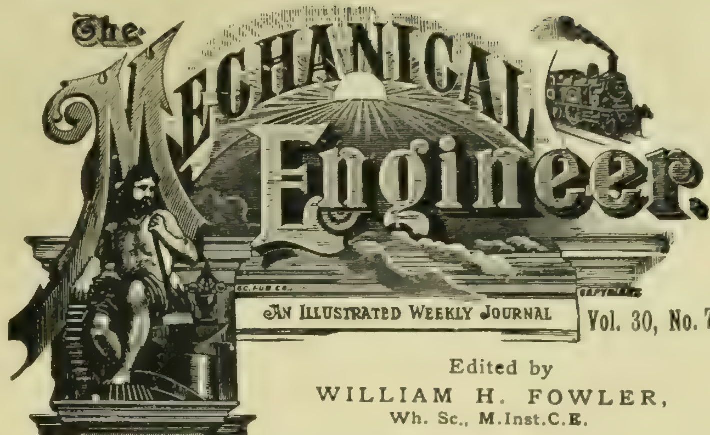
METAL QUOTATIONS.

TUESDAY, OCTOBER 22ND.

Aluminium ingot		82/- per cwt.
" wire, according to sizes, &c.	from	102/- "
" sheets " "	"	120/- "
Antimony	£37/-/- to	£39/-/- per ton.
Brass, rolled		9⅛d. per lb.
" tubes (brazed)		11¾d.
" " (solid drawn)		10d.
" " wire		9⅛d.
Copper, Standard		£74/17/6 per ton.
Iron, Cleveland		66/3 "
" Scotch		72/3 "
Lead, English		£20/15/- "
" Foreign (soft)		£20/10/- "
Mica (in original cases), small		6d. to 3/- per lb.
" " " medium		3/6 to 6/- "
" " " large		7/6 to 11/- "
Quicksilver		£8/-/- per bottle
Silver		29$\frac{1}{16}$d. per oz.
Spelter		£27/12/6 per ton.
Tin, block		£229/-/- "
Tin plates		15/7½ "
Zinc sheets (Silesian)		£31/5/- "
" (Stettin; Vieille Montagne)		£31/10/- "

The Cruiser "New Zealand's" Speed Record.—The cruiser "New Zealand," built by the Fairfield Shipbuilding and Engineering Company, Glasgow, and given by New Zealand to the British Navy, has completed exhaustive trials. She attained a speed of over 27 knots, which is the fastest on record for a vessel of her displacement. The "New Zealand" will return to Fairfield from Portsmouth within a few days for completion prior to being handed over for commission.

Proposed Union of Birmingham Technical Societies.—Efforts are now being made to form a Midland Technical Union, and a provisional committee, comprising members of all the important scientific and technical organisations in the district, has been appointed to deal with the matter. The immediate object of this provisional committee is the establishment of a technical library; joint office premises for the local technical and learned societies in the Midlands may follow. The societies considering the scheme are: The Midland Association of Gas Engineers and Managers, the Staffordshire Iron and Steel Institute, the Surveyors' Institution (Warwick and Worcester committee), the Institution of Mechanical Engineers, Institution of Electrical Engineers (Birmingham section), Association of Mining Electrical Engineers (Warwickshire and South Staffordshire branch), Birmingham Association of Mechanical Engineers, Birmingham Architectural Association, Birmingham Metallurgical Society, Midland Junior Gas Association, Institute of Metals (Birmingham section), Institution of Civil Engineers (Birmingham Association of Students), and the Society of Chemical Industry. If these societies decide to form a Midland Technical Union it will be the means, not only of strengthening separate organisations, but of bringing a large number of people with interests more or less allied into closer association.



Vol. 30, No. 771

Edited by
WILLIAM H. FOWLER,
Wh. Sc., M.Inst.C.E.

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High-lift Centrifugal Pumps.

ALTHOUGH the high-lift centrifugal pump has come into vogue to a considerable extent during the last few years, the principle of its working has been known for a long period. Osborne Reynolds was the first to demonstrate its practical application, and pumps of this kind were constructed over 30 years ago. But although the principle is simple, the reliable details of construction necessary to ensure adoption in practice has required a good deal of ingenuity and careful working out, and it was owing to defects in this direction that early attempts were not very successful, resembling in this respect the early developments of the steam turbine. The action of single-wheel fans or pumps is simple, air or water entering at the hub of a rotary impeller, consisting of radial arms working in an enclosed case, is ejected at the circumference with a velocity, depending on the speed of rotation, by the action of centrifugal force, and this velocity is converted partly into pressure and partly into internal eddying or heat, according to circumstances. In the case of fans this eddying effect, owing to the low density of air and the purpose for which it is generally used, is not of serious consequence, while it is not a serious item even with water when the pressure is low and the water moves with slow velocity. For this reason the single impeller centrifugal pump, on account of its simplicity and cheapness, has been widely adopted when large quantities of water have had to be pumped with small suctions and against low heads, as in harbour and drainage works. It is evident that if the pressure head created by a single impeller can be used as a starting pressure of a second and the delivery of this again for a third, the final pressure head may be made very great without using the high rotational speed which would be necessary if attempt were made to produce it in a single casing. This, in brief, is the theory of action of the high-lift centrifugal pumps as they are produced to-day. But its full realisation in practice, as we have intimated, has been a matter of slow development and the difficulties have

not been easily overcome. A most interesting description of them was given on Saturday last in a paper by Mr. W. E. Millington before the Manchester Association of Engineers, which we reproduce in detail elsewhere, and evidence of the success with which the difficulties have been overcome is afforded by the variety of purposes to which this type of pump is now being applied and the extent to which it is, on grounds of cheapness and efficiency, replacing pumps of the ordinary reciprocating type which, by comparison, all labour under the objection that the flow of water through them is more or less intermittent and their mechanism more complicated and thus more liable to derangement and more costly to repair.

The chief difficulty experienced in the early days of the multiple-stage centrifugal pump was the economic conversion of the velocity of discharge from the several units into static pressure to avoid internal eddying, which, when converted into heat, is irrecoverably lost. To effect this a considerable amount of abstruse calculations were at one time indulged in and much mystery made of the curves which should be followed in the passages guiding the delivery water from one stage to the inlet aperture of the succeeding stage. Experience has shown, however, that there is not so much in this as some designers have pretended and that considerable latitude is permissible, provided the passages themselves are ample and sudden enlargements and sharp bends avoided.

Another and greater difficulty that has since arisen as this type of pump has become popular and competition has led to higher speeds and greater pressure heads, is the thrust exerted in the direction of the axis, through the difference of pressure on the sides of the guide vanes. An analogous effect is produced in many types of steam turbines, and as in their case, many devices have been adopted in pumps, with a view to balancing this thrust and reducing the friction which must otherwise result. The use of thrust bearings was an obvious way out of the difficulty, but this has been attended with so much trouble that designers of centrifugal pumps have been forced to consider some way of effecting the balancing automatically. Considerable ingenuity has been spent in this direction and a variety of methods are employed. Many of them are described in the paper referred to, and it is sufficient to say that they have proved very efficient in practice and permit pumps of this kind to be operated with relatively unskilled labour. For this reason they are now extensively applied in mines and colonial work where skilled labour is difficult to obtain.

While pumps of this kind are capable of dealing practically with as great suction and delivery heads as almost any type of reciprocating pump for ordinary work, they possess certain limitations of which it is well to make note, for a failure to do so may lead to disappointment. They cannot, for instance, be subject to the wide changes of suction and delivery head permissible with reciprocating pumps and are therefore not suitable when serious fluctuations of this kind occur. It has to be remembered that the head due to friction increases approximately inversely as the fifth power of the diameter of the pipe and that since slight changes may affect efficiency the suction and delivery heads must be designed in the first place for the most economical friction head in any given case, and the small limits of allowable variation in this respect are well illustrated by the characteristic curves of an example in Mr. Millington's paper. These show that if, in the case of a pump designed to deliver 250 galls. per minute against a head of 175ft. when running at a speed of 1,400 revs. per minute, the head were increased to 185ft. (*i.e.*, less than 6 per cent.) the delivery would be reduced to 200 galls. (*i.e.*, by 20 per cent.), and that if the head were increased to 200ft. (*i.e.*, by 13½ per cent.) the pump at the speed named would not deliver any water at all. On the other hand, if the actual head were only 155ft. instead of 175ft. the delivery would be increased to 300 galls., with an expenditure of only 9 per cent. increase of power. The point obviously needs bearing in mind when pumps are operated by alternating-current motors whose speed is constant, and shows also the desirability of providing a margin of power to prevent overloading should the head be less than that for which it is designed.

It needs also to be remembered that the speeds and proportions of these pumps are designed to act in water, not in air, and that if the pump becomes charged with air the speed will not suffice to produce a vacuum and the suction may be destroyed and the pump fail to lift; for this reason air leakages or pockets in the suction pipe are more objectionable than in reciprocating pumps. For a similar reason also, centrifugal pumps need some method of priming with water to begin with. Again, owing to the complete absence of valves in the mechanism of the pump, it is necessary, especially with high lifts, to provide a non-return valve in the delivery main to prevent shock from "water-hammer" in the event of the pump being suddenly stopped for any reason through the column of water falling back on the suction foot valve. It is also desirable to insert a sluice valve in the delivery pipe as close to the pump as possible, as this permits the water delivered to be reduced from any cause. This method of regulation, it may be noted, is economical, as is shown by the low running torque of pumps when the valve is shut, and further, is not attended with any dangerous increase of pressure. One of the special advantages of this type of pump, in fact, is that the load imposed on a motor when starting a pump is very light, as the power is practically nil at very low speeds and gradually increases as the speed increases up to normal. Attempts to diminish the quantity of delivery by diminishing speed are liable to be very disappointing and are probably responsible for some of the troubles met with by inexperienced attendants, since the efficiency falls so rapidly with any reduction from the speed for which the pump is designed. A reduction of 5 per cent., for instance, may suffice to stop delivery altogether, though, on the other hand, the delivery may be increased by increasing the speed. With due attention, however, to the limitations of working of multiple-stage centrifugal pumps and to the good mechanical construction imperative where rotating parts run with small clearances, such pumps have a wide and growing field of usefulness. From their nature, however, they need to be high-class machines, and notwithstanding their fundamental simplicity, should be treated as such. They are not suited to dirty water or the rough and tumble duties which occasionally fall to the lot of the ordinary reciprocating type, although, where conditions permit, they are in some ways superior.

Launch of a New Dreadnought.—There was launched at Devonport Dockyard on the 24th ult., the "Marlborough," which is the 20th battle-ship of the Dreadnought class constructed for the British Fleet. The vessel belongs to the Iron Duke class, and, in addition to a main armament of ten 13·5in. guns, will mount sixteen 6in. guns. The former fire a projectile weighing 1,400lbs., and the latter fire 100lb. shells. Compared with H.M.S. "Dreadnought," the "Marlborough" is 70ft. longer, 8ft. wider, and when completed will be 7,000 tons heavier than the first of her class. Her actual length is 580ft., beam 90ft., and displacement 25,000 tons. The order for the engines has been placed with R. & W. Hawthorn, Leslie, & Co., Ltd., and will comprise Parsons steam turbines, arranged for four screws. The specified horse-power is 33,000, with a speed of not less than 21 knots.

DEVELOPMENT IN MARINE ENGINEERING.

Sir Charles Parsons, in his presidential address, delivered at the opening meeting of the 29th session of the North-east Coast Institution of Engineers and Shipbuilders, referred to the changes that had taken place in the last 28 years in marine engineering and shipbuilding. He also traced the history of the application of steam for the propulsion of vessels, the "Comet," in 1812, being the first real practical success in British waters, and said it indeed seemed that the reciprocating engine was not now capable of much further improvement. The turbine alone had superseded the reciprocating engine in fast vessels, chiefly because of its superior economy in fuel, the direct result of its greater range of expansion, or, in other words, its power of utilising the expansive energy of steam right down to the pressure in the condenser, and fulfilling more completely the laws discovered by Watt. The total horse-power of the world's shipping had been recently estimated at about 26,000,000, and of this about 8,500,000 was now provided by turbines. The turbine was, however, ill adapted for direct coupling to the screws of slow ships, but the application of gearing removed this embargo, and by its use both the propeller and the turbine were allowed to run at such speeds of revolution as were most suitable to give the greatest propulsive horse-power in proportion to the steam used. The three principal types of reduction gear at present were the hydraulic, the electric, and the helically cut mechanical gear. Which of these was preferable depended on considerations of efficiency, first cost, weight, durability, and reliability.

The supersession of jet condensers by surface condensers in the fifties had, he said, removed to a large extent the difficulty arising from the presence of salt in the boilers, inseparable from jet condensation. Condensers, however, had to be kept tight and feed make up apparatus provided of sufficient capacity to supply the boilers with fresh water. At one period these conditions could not always be ensured, but of late years condenser troubles, which generally took the form of corrosion and perforation of the tubes, had been largely overcome, feed filters had been introduced, and as a consequence superheaters were now being adopted more extensively and successfully. The present position seemed to be that, with reasonable care to the exclusion of salt from the boilers, well-designed superheaters were a practical success at sea, and resulted in a considerable and important saving of fuel.

The application of the Diesel engine to large vessels such as the "Selandia," and Dr. Diesel's recent enthusiastic advocacy of heavy oils at the Institution of Mechanical Engineers, and Sir Marcus Samuel's statements as to the amount and probable price of such oils had, he observed, tended to distort the public mind upon this subject. For comparatively small and moderate powers, as viewed by the marine engineer, internal-combustion engines had proved eminently satisfactory, and the economy of fuel for such sizes was very much superior to that of steam engines; chiefly because they had almost entirely superseded the latter for small powers. On the other hand, as the size increased their relative superiority diminished, until in the case of the largest steam units, as compared with the largest internal-combustion units hitherto constructed, there was very little difference in the consumption of fuel between the two. At the present time the position seemed to be that, in regard to marine work, the only satisfactory means of constructing a large internal-combustion unit of power for gas or oil was to multiply the cylinders.

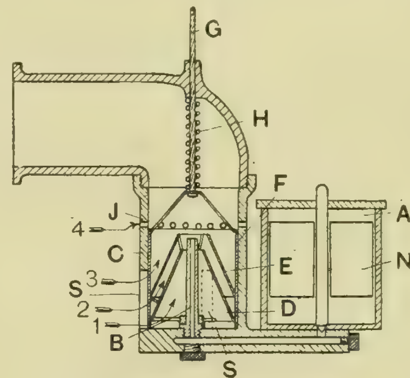
From the discussion at the Institute last summer on the relative merits of the internal-combustion engine using oil or gasified coal, as compared with the steam engine and steam turbine, when applied to a modern cargo vessel of average size, it appeared that a lower price for oil than 50s. seemed to be needed to enable it to compete as fuel in internal-combustion engines with coal burnt under boilers and modern steam engines and geared turbines. There were, however, exceptional cases of vessels that had to perform very long voyages carrying their own fuel where the advantages of a minimum consumption were paramount. On the other hand, there were cases less favourable to oil, and the short experience of large oil engines on board ship made speculation difficult as yet, and it remained for further experience over a term of years before definite figures were available as to upkeep and reliability.

With regard to gas turbines, he mentioned that a few experiments which he made many years ago, some of them directed to ascertain the possibility of the gas turbine, convinced him that, with the metals now at disposal, the cylinder and piston was the best way of utilising the power of gaseous explosions, and that to attempt to cause flame, whether at full heat or cooled by admixture of steam or water to impinge on blades was the wrong method of utilising the power. He had studied the subject very closely up to the present time, and was still of the same opinion. On the whole he was inclined to think that possibly a more hopeful course than that of working on the lines of the gas turbine or the gas-propelled water turbine would be found in some form of rotary engine of the piston type, in spite of such constructions having, after numerous attempts, been failures as steam engines.

FIELDING'S CARBURETTER FOR OIL ENGINES.

The carburetter shown in the accompanying sectional view has recently been patented by Mr. A. Fielding, Dawson's Croft, Salford, Manchester. It has been designed more particularly for the engines of motor vehicles, and with a view to enable the heavier hydro-carbons to be used. The arrangement comprises a float chamber A containing the petrol or other hydro-carbon, a float N, an adjustable jet B, and a mixing chamber C. Around the jet B is secured a cone D. On this cone is fitted a second cone E, both cones being surrounded by a cylinder F, so constructed as to be a sliding fit in the mixing chamber C, and connected to a wire G actuated by a lever under the control of the driver, and is held normally down in the position shown by a spring H. In the mixing chamber C are three slots S forming air ports, which are gradually opened as the sliding cylinder F is raised, and so allowing atmospheric air to rush into the mixing chamber C past the jet B.

In operation, when the engine is starting or is running dead slow, the sliding cylinder F is raised sufficiently to allow primary air to rush in at a high velocity through the ports S in the direction indicated by the arrow 1, up the cone D and past the jet B, and as the speed of the engine increases the sliding cylinder F is raised further and secondary air



Fielding's Carburetter.

is admitted through the ports S and rushes at a high velocity up the second cone E, as indicated by the arrow 2, and past the jet B, and if the sliding cylinder F is raised still further, tertiary air from the ports S enters the mixing chamber and rushes up the outside of the cone E. When running down hill the supply of air and petrol or like hydro-carbon may be cut off partially or wholly as required, and when entirely cut off the engine will draw in and pump air, which enters, as indicated by the arrow 4, through a series of apertures J in the mixing chamber C, thus scavenging and cooling the power cylinder. As soon as the carburetter is again brought into action by raising the sliding cylinder F the apertures J are closed, and the admission of air to the jet B takes place as already described.

From the foregoing it will be readily understood that the degree of richness of the explosive fluid mixture is controlled by the position of the sliding cylinder F, acting in conjunction with the cones D and E, the cylinder F being raised or lowered in accordance with the required speed of the engine and the requirements of its load or the work to be done. Further, for high speeds the velocity of the air currents will be higher, and as for high speeds a weaker mixture is required, the velocity of air past the jet will be less as the sliding cylinder F is raised, since extra air will enter and pass up round the cone E, as indicated by the arrows 2 and 3, and the lower the speed the richer the mixture if the cylinder F be partly closed.

HEAVY OIL ENGINES.*

BY CAPT. H. RIALL SANKEY, R.E. (RETIRED), M.INST.C.E.

(*Continued from page 513.*)

15. *Fuel Valve.*—The details of these valves vary, but in all of them arrangements are adopted to break up or pulverise the oil by violently blowing it against surfaces placed opposite to small holes. Thus, as shown in Fig. 16, a series of discs having numerous holes are slung on to a central stem; the holes are staggered so that those in one disc are opposite the spaces in the holes of the next disc. At the bottom of the row of discs there is a grooved conical casting fitted into a

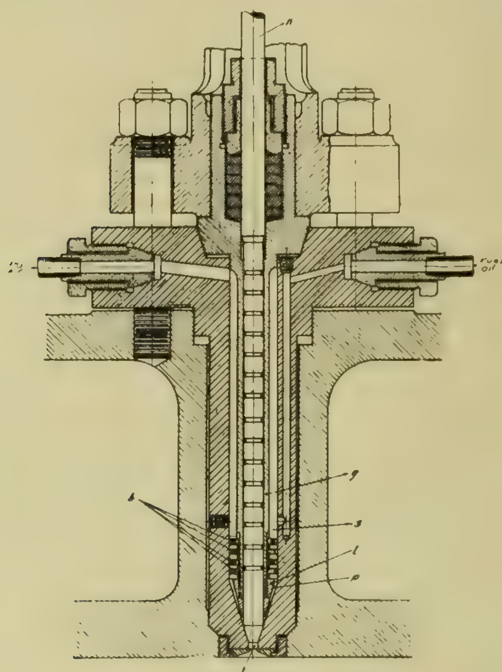


FIG. 16.

cone through which the pulverised oil has to rush, and thence through a small hole at the bottom of the valve casing placed on a level with the cylinder top, and which is closed at other times by a needle valve. The lift of the needle valve is only about $\frac{1}{500}$in.; great care is therefore necessary in fitting the levers actuating the fuel valve.

The fuel valve of the American Diesel engine is shown in Fig. 17, and it is placed horizontally. As the injection valve opens, air and oil, being divided into small streams by a circle of holes, are forced into the injection nozzle, where these streams impinge upon each other, thus atomising the fuel.

16. *Exhaust Valve.*—The exhaust valve is an ordinary mushroom valve, opening into the cylinder and held against its seat by a spring, as shown in Fig. 18, and opened by the exhaust lever at the proper point of the stroke, viz., at about 75 per cent. This valve is allowed to close at about 1 per cent. after the dead centre.

17. *Air Suction Valve.*—This is substantially the same as the exhaust valve (see Fig. 18). It opens 4 per cent. before the upper dead centre, and closes 2 per cent. from the bottom dead centre. Both the exhaust and air valves have their own seating, which is secured into the cylinder cover. This permits of harder cast iron being used for the valve seatings, and assists overhauling and cleaning of the valves, because the valve and its seating can be bodily removed and replaced by spares. The valves open inwards into the cylinders, and are held on their seats by springs. As already stated, they are opened by means of rocking levers.

18. *Air Compressor.*—The air compressor has to be capable of compressing air up to 1,000lbs. per square inch, and must therefore be at least of the two-stage variety. Many makers, however, such as Carels and Sulzers, adopt a three-stage compressor. Between the stages the air is cooled. The compressor is driven from the end of the crank shaft by a crank. Usually it is of the reciprocating type, either vertical or horizontal, and in many cases the Reavell type of compressor is used, as in the Willans-Diesel engines. It is a vital part of the engine, and is probably one of those most likely to give trouble.

19. *Compressed-air Vessels.*—There are generally three of these vessels, or storage bottles—two to act as reservoirs for starting the engine, and a smaller one acting as an air vessel on the compressor to keep the pressure steady. They should be placed as close as possible to the engine, and are connected thereto by copper pipes. There is a gauge to show the pressure of air being delivered to the engine, which varies from about 950lbs. per square inch for full load to 750lbs. per square inch for quarter load. If, however, the load is varying continually the pressure must be maintained for the maximum load. The object of reducing the pressure is as follows—a definite air supply is required for burning the oil. This air is partially supplied by the air compressed in the cylinder and partly by that injected to pulverise the oil. At light loads less air is needed than at heavy loads, and, as the air compressed in the cylinder is constant in amount, that introduced by injection must be reduced, which is effected by reducing the pressure. The two starting vessels are connected to one of the engine cylinders, and the connection is made by a special lever and cam, as already described, and the compressed air is admitted at each stroke until firing takes place. Water collects in the storage bottles, and therefore drainage should be provided. The air supply is more than three times that theoretically required, and the supply is the same whether the engine is running fast or slow—a point which is of interest only for marine engines.

20. *Fuel Pump.*—The design shown in Fig. 19 consists of an ordinary plunger pump worked by an eccentric off the two-to-one shaft. On the plunger lifting, the foot valve opens and oil is sucked in. On the return stroke the foot valve is held open by the governor until just sufficient oil remains to deal with the load then on the engine. This quantity of oil is then forced through the fuel valve. Makers disagree as to whether each cylinder should have its own fuel pump, or whether one larger fuel pump should be supplied for all the cylinders. In the former case, the casing of the pump contains a plunger for each cylinder, each with its own delivery. In the other case the oil is delivered into a chamber, from which copper pipes lead to the fuel valve of each cylinder, with an adjusting valve, so that each cylinder will get the same amount of oil.

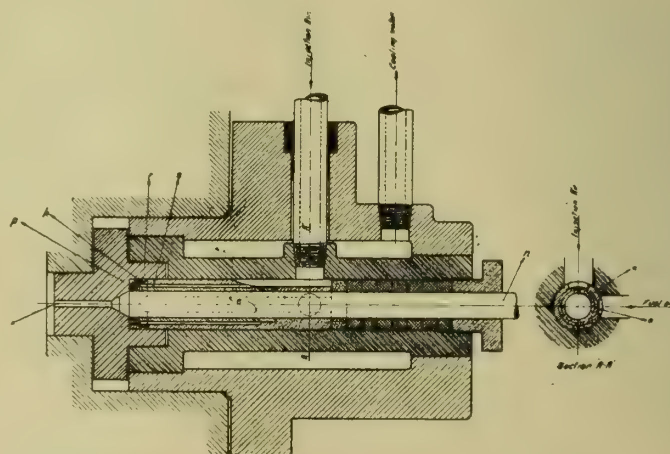


FIG. 17.

21. *Fuel Tank.*—A small tank is provided with sufficient head for the oil to flow by gravity to the fuel pump. The casing should be warmed to make the oil more fluid, and this can be done by means of the exhaust. The oil is pumped from barrels, or from a storage tank, into the fuel tank by means of a hand pump.

22. *Governor.*—The usual centrifugal loaded type of governor is used, driven from the vertical shaft already referred to, and it acts on the foot valve of the fuel pump. There is generally an arrangement, actuated by a small hand-wheel working on a spring, as shown in Fig. 19, for altering

* Howard lectures delivered before the Royal Society of Arts, April-May, 1912. Reproduced from the "Journal of the Royal Society of Arts."

the setting of the governor, by means of which the speed of the engine can be varied from 5 to 10 per cent. whilst the engine is running.

23. *Exhaust Pipe.*—Heavy cast-iron breeches pieces are taken from each cylinder exhaust and connected into one pipe. These are led generally downwards to a large silencing vessel. The pipe then rises again, and can be fitted at the top with any ordinary baffle type of silencer.

The ordinary slow-speed Diesel engine weighs from 500lbs. to 600lbs. per brake horse-power, as against 100lbs. per brake horse-power for a steam engine of the same number of cylinders, of the same power, and running at the same speed. In the case of the steam engine, however, the weight of the boiler

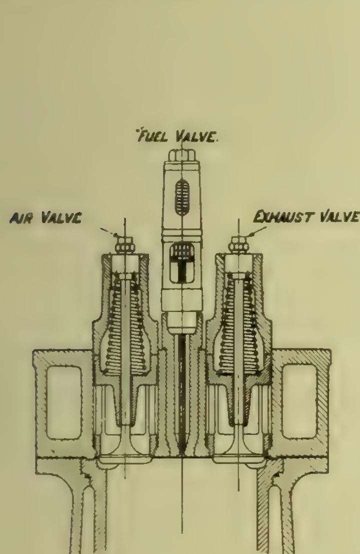
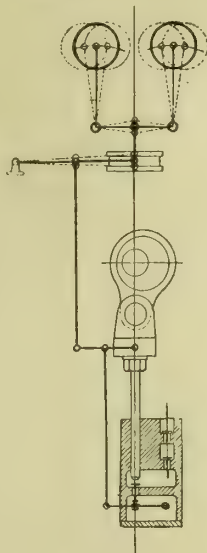


FIG. 18.


FIG. 19.

and accessories, such as condensers, feed pumps, air pumps, &c., must be added, and this weight is approximately 250lbs. per brake horse-power, or a total of 350lbs. per brake horse-power. By increasing the speed and lightening the scantlings, as is done with the engines used in torpedo boats and submarines, the weight of the Diesel engine has been reduced to about 50lbs. per brake horse-power, or even less.

The above description refers specially to vertical engines, but comparatively recently the Maschinenfabrik Augsburg-Nürnberg Company have placed on the market a horizontal Diesel engine. According to Dr. Diesel, this, at first, was merely a vertical engine placed on its side. The more recent examples, however, are substantially the same as the horizontal gas engines of the well-known make of the Maschinenfabrik Augsburg-Nürnberg Company, and, according to these makers, the horizontal engine really becomes of advantage after about 500 b.h.p. The main reasons for preference are based on the facilities for overhauling, and there is the further advantage that cylinders can be readily placed in tandem. The design of the tandem double-acting Diesel oil engine is almost indistinguishable from that of their horizontal double-acting gas engine; the exhaust valve is the same, the air gas valve is replaced by an air valve, and the sparking plugs by the fuel valve. In the case of this horizontal Diesel engine the valves are actuated by cams, whereas, in the case of the gas engine, eccentrics are used in combination with variable fulcrum levers. This difference in valve driving is, however, to a great extent, a matter of taste.

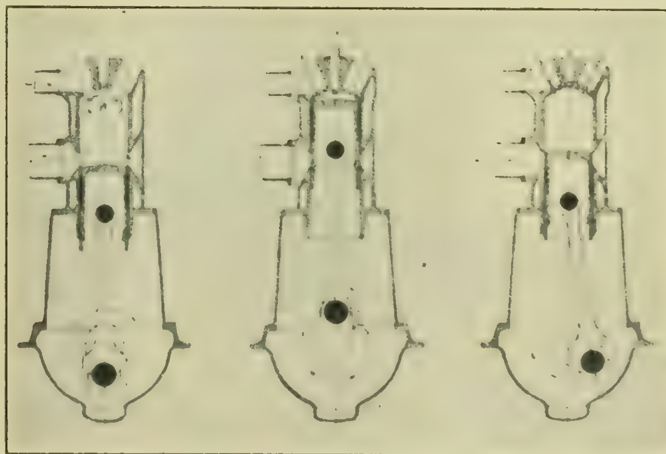
For large engines the pistons have to be cooled, and if the engine is vertical any leakage of cooling water—which somewhat readily occurs—will fall into the crank chamber and will interfere with the lubricating oil. For this reason, it has been found necessary to cool the pistons of vertical engines by means of oil, as is done by Messrs. Sulzer. In the case of the horizontal engine, the cooling water cannot mix up with the lubricating oil, and there is no difficulty therefore in water-cooling the pistons in exactly the same way as is done with horizontal gas engines.

The details of construction just described have special reference to the four-stroke engine. Many of them, however, apply also to the two-stroke engine without alteration, such as the fuel valve and the air compressor, the framing, crank shaft, and connecting rod. Others, such as the cam shaft and cylinders, are modified, and in order to scavenge the exhaust and introduce pure air into the cylinder at the bottom of the stroke, as already mentioned, an air blower or compressor, capable of giving a pressure of from 4lbs. to 8lbs. per square inch, has to be provided in addition. As regards removal of the exhaust, two systems are adopted. In one of these, as adopted for smaller engines by Messrs. Sulzer and by Messrs. Carels, scavenging valves are placed in the cylinder cover, which are similar in construction to the exhaust valves. In the larger engines and in the marine engines, however, the scavenging valves are placed at the bottom of the cylinder. They are also placed in the air pipe, and then are made as piston valves.

In the other arrangement adopted, for example, by the Maschinenfabrik Augsburg-Nürnberg Company, ports are cut in the cylinder which are uncovered by the piston at the bottom of the stroke. The air enters the cylinder by the ports on one side, and the exhaust is expelled at the other side of the cylinder, as is done in many two-stroke petrol engines—for example, the Day engine. Figs. 20 and 21 show the two arrangements above described.

The air blast is also obtained in two different ways—(1) by a separate blower, and (2) by enlarging the piston at the bottom to form an air-compressing cylinder placed under the combustion cylinders. Messrs. Carels use a double-acting pump driven by levers off the cross-head, following the marine practice of driving the air pump. Messrs. Sulzer use an air compressor driven by an eccentric from the crank shaft. Another arrangement is to have separate vertical compressing cylinders driven direct by the crank shaft, and in the marine Maschinenfabrik Augsburg-Nürnberg Company engines, for the two-stroke single-acting engine a large trunk piston arrangement is used, while for the two-stroke double-acting engine they use a separate blower.

The scantlings of the two-stroke engine are substantially the same as those of the four-stroke engine of the same cylinder diameter, but it must be remembered that nearly double the power is obtained. The turning effort is better, as will be obvious from Fig. 10, and therefore a smaller flywheel can be used to obtain the same degree of regularity. The fuel consumption per brake horse-power is, however, somewhat higher owing to the extra work required for the air scavenging, and the stroke of the engine has to be made about 10 per cent.


FIG. 20.

longer, to allow for the idle portion of the travel while covering or uncovering the lower exhaust ports. The initial cost is stated by Dr. Diesel to be about 20 per cent. less than that of the four-stroke cycle.

Four cubic feet of free air compressed to from 4lbs. to 8lbs. per square inch is an ample allowance per brake horse-power per minute. Thus, in the case of two 5,000 b.h.p. engines, 40,000 cub. ft. of free air would be required to be compressed per minute to about 5lbs., and this would probably be most effectively done by means of a turbo-blower.

Another estimate is that 100 cub. ft. of air at 2½lbs. per

square inch are required per second for a 2,500 i.h.p. engine, which is equivalent to 2·8 cub. ft. of free air per brake horse-power per minute. The volume swept by the scavenging air pump should be considerably greater than that swept by the engine piston, say, 1·8 times. For marine work it is desirable to have two scavenging pumps—one as a stand-by.

Marine Diesel Engine.—Up to the present single-acting engines have been considered, but either the four-stroke or the two-stroke type can be arranged to work double-acting In this case the ordinary box piston has to be used, together with a piston rod and its gland. The piston rod has to be of large diameter owing to the stresses to be resisted, and, owing to the high temperatures to which they are exposed, considerable difficulties have arisen with the piston glands.

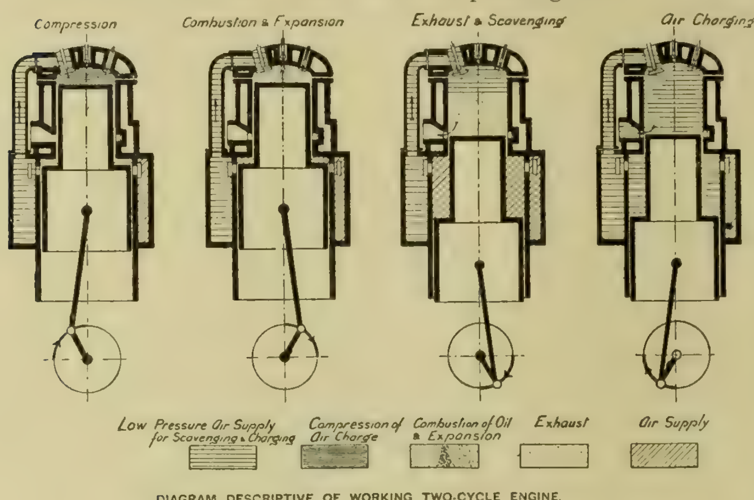


DIAGRAM DESCRIPTIVE OF WORKING TWO-CYCLE ENGINE.

FIG. 21.

For marine work a special type of Diesel engine has been developed, because, in the first place, a reversing engine is needed, and, secondly, space and weight are of extreme importance. This last requirement has, of course, a greater importance in the case of destroyers, submarines, and such like, than for tramp steamers. Thirdly, flywheels are objectionable, and ready starting and stopping are essential. Dr. Diesel says: "It can now be stated with certainty that the marine engine of the future is to be of the double-acting, two-stroke cycle type."

In a recent design of the Maschinenfabrik Augsburg-Nürnberg Company marine engine of the single-acting type, a piston rod without gland has been connected to a cross-head working on the ordinary guides as in a marine engine. The piston rod is not rigidly fixed to the piston, but is connected thereto by means of a pin. This gives freedom to the piston and prevents any cross stresses.

The reversing of marine engines was originally effected either by means of clutches or else electrically. Later, arrangements were adopted for altering the timing of the valves, but in the four-stroke cycle the solution is somewhat complicated. For example, in the "Selandia" the two-to-one shaft is lifted bodily and displaced longitudinally so as to bring another set of cams into operation, then on stopping and restarting the engine runs in the opposite direction.

With the two-stroke cycle the solution is extremely simple, because a shift of 30° is sufficient to alter the lead of the valve from the "ahead" to the "astern" position. This shift is effected in the Maschinenfabrik Augsburg-Nürnberg Company engine by having a coupling on the vertical shaft with two stops 30° apart. The coupling comes against one stop for the ahead position, and to go astern there is lost motion to the extent of 30° to come up to the other stop. In the Carels engine the vertical driving shaft has spiral wheels, which are revolved by the starting gear to give the necessary shift of 30°. The reason why a shift of 30° will reverse a two-stroke engine will best be seen by the valve diagram shown in Fig. 22.* On the left-hand diagram, F shows the point of fuel admission, γ being the angle of advance. F′ is the point at which the fuel valve closes. S is the point at which the exhaust opens with a lead angle of π, and S′ is the point of closing the exhaust. It will be seen that the angle ϵ is equal to the angle between F and F′, less twice the angle of advance, and is also equal to the angle between S and S′, less twice the angle of lead. Hence, if the timing of all the valves is shifted by the angle ϵ, as indicated by the dotted lines in the right-hand diagram, the opening and closing of the valves will be correctly adjusted for reversing. This angle ϵ is about 30°, and the shift is effected as above described.

* Reproduced by permission of the "Engineer."

As regards the general design of marine Diesel engines, according to Mr. Milton only the cylinders should be "Diesel," and the motion and framework should follow exactly present marine practice.

Number of Cylinders.—The number of cylinders to be employed is a somewhat vexed question, and the tendency is to use a great many, and for two reasons: First, unless water-cooled or oil-cooled, 24in. seems to be the largest cylinder possible, and from such a cylinder at 200 revs. per minute the brake horse-power obtainable is 400 on the 2-stroke cycle. When the piston is either water-cooled or oil-cooled, much larger cylinders can be employed, and it would appear that 2,000 h.p. per cylinder is then obtainable. Experiments have been made with these large cylinders by the Maschinenfabrik Augsburg-Nürnberg Company and by Messrs. Sulzer, and, so far, have been satisfactory; but no doubt some time must yet elapse before it can be said with certainty that the present arrangements are really practically satisfactory. The second reason is that many cylinders are needed to obtain a uniform turning moment, depending again, however, on whether the engine is four-stroke or two-stroke, and whether it is single-acting or double-acting.

For land work, so far, moderate sizes are being used, and large flywheels are not objectionable, and are in some cases necessary to cope with the external changes of load. Sometimes the rotor of a dynamo supplies a large portion of the flywheel effect. Four lines appear to be the maximum used; three lines are very common, and for smaller sets two lines

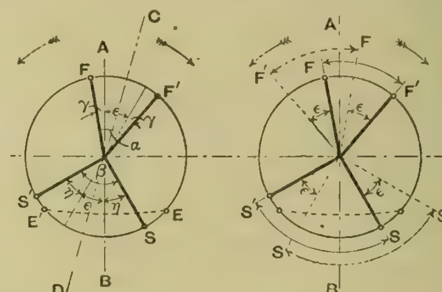


FIG. 22.

and even one are suitable. For marine engines, however, flywheels are objectionable for manœuvring and reversing reasons, and as a rule the engines are of larger power, and hence six lines, and even eight lines are common. Except for horizontal engines tandem cylinders are not used.

(To be continued.)

Institute of Metals: Birmingham Section.—At the annual meeting of the Birmingham section of the Institute of Metals, Prof. Turner said a good metallurgist required many qualifications beyond his scientific training. He was confronted, on the one hand, with problems dealing with large outputs, mechanical handling, rapid transit, the standardisation of patterns, and huge capitalisation. On the other hand, the metallurgist had to deal with the microscope or ultra-microscope in connection with the properties of metals, and the effect of minute pieces of impurities or of changes of temperature upon those properties. In the local metal trades, Prof. Turner added, a subject of great interest at the present time was the effect produced upon metals by working them in a cold state, as the result of which they became harder, stronger, and less ductile. Only certain metals could be hardened in this way, and these only within definite ranges of temperature. Prof. Turner then proceeded, by means of lantern slides, to illustrate modern conceptions of the internal structures of metals and the growth and arrangement of the constituent crystals. He showed how those crystals were broken up and deformed during the process of working, and how, when these hardened, a metal could be caused to recrystallise and soften by proper heat treatment. In conclusion, he laid special stress on the evil effects of improper annealing.

DEVELOPMENT IN AUXILIARY UNITS BETWEEN EXHAUST PIPE AND BOILER.*

BY WILLIAM WEIR.

I PROPOSE to set out first the sequence in which the principles involved in the development of auxiliary machinery were originally enunciated, and, thereafter, to consider the practical embodiment of these principles in various forms of apparatus, together with some typical results of performance

The chain of auxiliary machinery involved in the treatment of exhaust steam from the exhaust pipe to the boiler is constituted by the following links: Condenser, circulating pump, air pump, feed-heating apparatus, feed-pumping apparatus, and feed make-up apparatus.

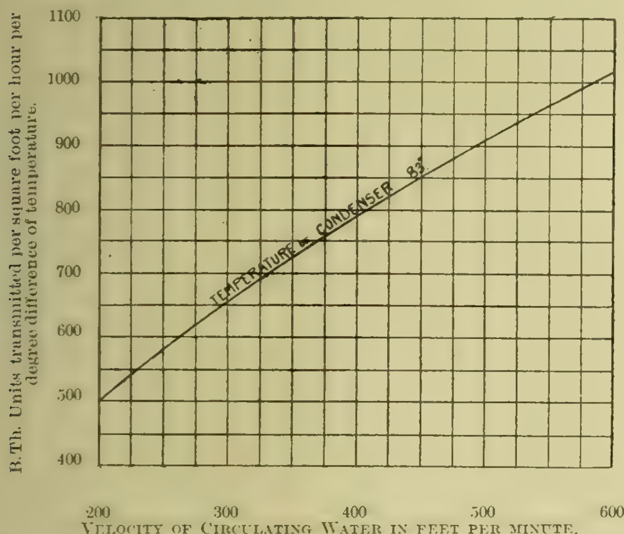


FIG. 1.—TRANSMISSION-RATE DIAGRAM.

All important engineering developments appear to take place in two stages, an initial stage characterised by the consideration of and experimental research into the phenomena, and the discovery and formulation of the main principles governing these phenomena; and a second stage characterised by the development of the design and details of the apparatus necessary to perform the desired functions.

The latter stage involves the modifications necessitated bv experience in actual working. The fact that present-day interest is more largely concerned with the perfecting of the apparatus itself makes it the more necessary to keep in view and to record the main principles, for, while the details of design are merely temporary phases, the principles are permanent. In stating the principles I have arranged them according to the respective apparatus, and have annexed the approximate dates when they were enunciated:—

SURFACE CONDENSERS.—1879.

1. In an efficient surface condenser the steam should take such a course that it will flow over all the tubes and at a uniform velocity, and no spaces should be left which permit of short circuiting.

2. The steam inlet to a condenser should be arranged as far as possible from the air outlet.

3. The circulating water course should be as nearly as possible opposite to that of the steam.

4. To obtain the maximum hot-well temperature the entering steam should make contact with the condensed water.

5. To obtain 4, separate outlets should be provided for air and condensed water.

6. To obtain 4, separate pumps must be employed for air and water, but on emergency the water pump should handle air and water, and the air pump also handle water.

7. To obtain maximum efficiency from the air pump it should be cooled itself, or the air and vapour cooled in the suction passage.

1891.

8. The provision of an air-cooling compartment in a surface condenser.

9. Submerged cooling surface for specially cooling condensed steam.

10. Extraction of condensed water by a pump controlled by float gear in the condenser.

FEED HEATING.—1871.

1. In marine installations the use of auxiliary exhaust steam for feed heating.

2. Heating feed water of surface-condensing engines up to the temperature of the low-pressure cylinder exhaust by passing the feed water into a heater arranged between the low-pressure cylinder and the condenser.

Note.—This shows an early appreciation of the pressure and temperature difference between the condenser and the low-pressure cylinder imposed by ports and passages.

1876.

3. Heating feed water by a part of the steam used in the engine before the expansion of the steam is complete.

4. Feed heating at successive pressure stages with portions of steam which have worked to different extents in a multi-expansion engine.

AIR AND CONDENSED-WATER PUMP.—1871.

1. The pumping of water at its evaporation temperature by means of one pump discharging into another to create an artificial head on the second pump.

1871.

2. The provision of 3-way steam, water, and air eductors for removing air from condensers.

1879.

3. Separate pumps for air and water.

4. Rotary continuous-action pumps as water-extraction pumps for condensers.

1880.

5. The provision of a steam jet to give a head or pressure to water drawn from a condenser to enable it to pass to the air pump.

FEED PUMPS.—1880.

1. Feeding boilers by an independent steam pump, the speed being controlled by a float acted on by the feed water.

BOILER CORROSION.—1876.

1. The separation of air and corrosive gases from feed water to prevent boiler corrosion by subjecting the feed water to an increase in temperature with a reduction of pressure in a direct-contact feed heater.

2. Preventing boiler corrosion by taking the feed water direct from the condenser and discharging it to the boiler.

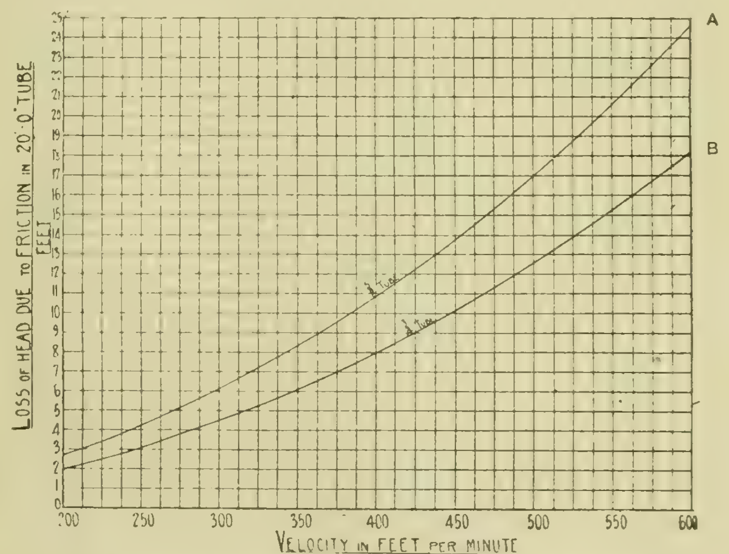


FIG. 2. FRICTIONAL HEAD DIAGRAM. A, ⅝in. tube; B, ¾in. tube.

EVAPORATORS.—1884.

1. Using the vapour from the evaporator to do work in the main engines.

2. Using steam which has already done work in the main or auxiliary engines in the evaporators.

Note.—This is the system universally used in H.M. Navy, and is termed the "closed exhaust system."

GENERAL.—1884.

Working steam through one expansive stage in an

* Paper read before the Institution of Engineers and Shipbuilders, in Scotland, October 22nd, 1912.

auxiliary engine, and then working the same steam through additional stages or stage in the main engines.

Note.—This practice is now almost universal on turbine-propelled warships, as the auxiliary exhausts invariably are connected to the low-pressure turbine.

The foregoing main principles, naturally coincided with an investigation into and enunciation of a very large number of

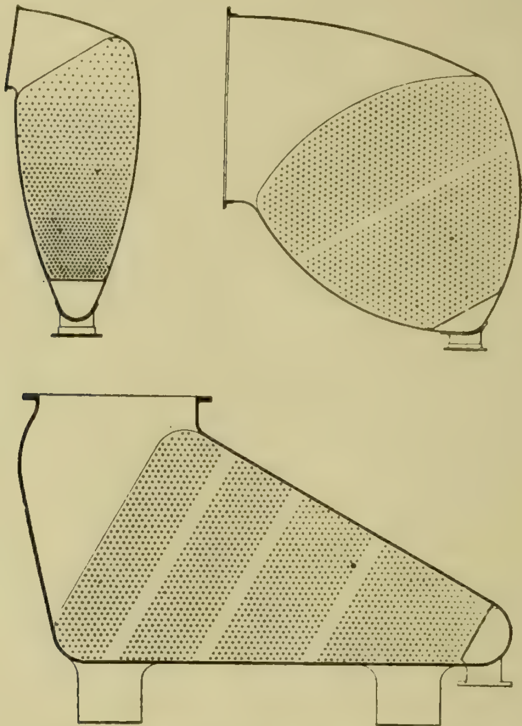


FIG. 3.—REPRESENTATIVE TUBE PLATE DIAGRAMS.

subsidiary factors, but, broadly speaking, the developments in actual practice which I now propose to indicate have proceeded from the above enunciations, while, in addition, the apparatus has required to conform to the many known physical laws and conditions affecting the various problems.

SURFACE CONDENSERS.

In dealing with the question of condenser design I shall adhere to the method of development already indicated; considering first the physical conditions affecting the problem, and from them deducing certain general principles. The application of these principles, involving the use of experimental data, will then form the basis of design. Viewed broadly, a surface condenser is an apparatus wherein a heat exchange takes place between exhaust steam and sea water. The main factors controlling this exchange are: (1) The temperature difference between the steam and the water; (2) the velocity of the steam; (3) the velocity of the water; (4) the presence of non-condensable gases in the steam; and, to a lesser extent, (5) the mean temperature of the steam and water.

The conditions to which a well-designed condenser for marine use and for any specific vacuum and sea temperature should conform are: (1) Minimum weight and space; (2) minimum power absorbed by circulating pump; (3) minimum cooling of condensed water; (4) minimum variation of pressure on the steam side.

The principles of correct design should emerge when the effect of the above desiderata on the factors governing the heat exchange is considered. Assume in the first place that, as the result of experience, it is found that the most practical constructional form of apparatus in which the steam and water can be brought into contact is one in which the water passes through a number of small tubes inside a containing vessel to which the steam is introduced. If the apparatus is to be limited to this type, it follows that the province of condenser design lies in the proportioning of the respective paths of the two fluids. The paths may conveniently be considered separately and the conditions of each noted. The steam path must be such that the maximum velocity is attainable with the minimum loss of head. Obviously then the path must be, as nearly as possible, straight, and the velocity must be maintained constant in value. The first condition precludes the use of baffle-plates, the second necessitates a varying cross-sectional area, which should, in fact, vary in proportion to the condensation. The only other factor directly influencing the contour of the steam path is the quantity of non-condensable gases present. Maximum efficiency requires that this quantity should be kept at a minimum. This constitutes the function of the air pump.

It is to be noted that the steam path has been considered without reference to its condition—condensed or non-condensed. Where one pump is used both as air pump and condensed-water pump, the path of the steam will necessarily be identical with that of the condensed water. Where separate pumps are used, however, it will be possible to treat the vapour and water differently, and to give them different paths. Whether it will be advisable to do so or

TABLE I.—*Typical "Uniflux" Condenser Data and Performances.*

Installation No.	Class of Installation.	Type of Engine.	Horse-power.	Steam Consumption, lbs. per hour.	Cooling Surface, sq. ft.	Condensation rate in lbs. sq. ft.	Guaranteed Vacuum 30in. Bar.	Sea Temperature, Deg. Fah.	Performances. Actual Vacuum 30in. Bar.	Sea Temperature, Deg. Fah.	Temperature Circulating Water Outlet.	Hot-well Temperature, Deg. Fah.	Diff. in Deg. Fah. from theoretical Outlet Temperature.	Diff. in Deg. Fah. from theoretical Hot-well Temperature.	Tubes. Diameter. Thickness. Length.	No. of Flows.	Type of Air Pump.
1	Small mail steamer..	Reciprocating	5,800	87,000	3,282	26·5	25·5	55	26·8	44	110	110	6	6	¾in. 18in. W.G. 7ft. 8¼in.overall	3	Engine-driven Edwards
2	Mediterranean mail steamer.	,,	12,000	180,000	8,000	22·5	26	60	27·7	72	99	104	6	1	¾in. 18in. W.G. 7ft. 6in. overall	3	,,
3	English Channel steamer.	Turbine	12,000	180,000	8,636	20·8	28·5	55	28·95	49	69	69	9·5	9·5	¾in. 18in. W.G. 10ft. overall	2	Independent "Dual"
4	Intermediate Atlantic liner.	Reciprocating	12,000	171,000	8,410	20·6	27	60	27·2	53	103	98	9	14	¾in. 18in. W.G. 10ft. overall	2	,,
5	Fast cruiser	Turbine	22,000	340,000	16,820	20·25	28·25	55	28·8	54	75	78	8	5	⅝in. 18in. W.G. 7ft. 6in. overall	2	,,
6	Battle-ship	,,	27,000	418,500	21,600	19·375	28·5	55	28·85	57	76	76	5	5	⅝in. 18in. W.G. 8ft. overall	2	,,
7	Destroyer	,,	17,000	240,000	9,000	26·7	28	55	28·55	45	78	78	11	11	⅝in. 18in. W.G. 15ft. overall	1	,,
8	A London Power Station.	,,	2,000kw	28,800	3,000	9·6	28	75	28·1	75	95	95	3	3	⅝in. 18in. W.G. 6ft 2¾in. overall	4	,,
9	Large cargo steamer	Reciprocating	5,300	80,000	4,100	18	25	85	27·3 26·75	44 84	105 106	111 106	6 11	0 11	¾in. 18in. W.G. 7ft. 6in. overall	3	Engine-driven "Dual"
10	Fast yacht	Turbine	2,500	46,000	1,300	35·4	27	55	27·3	54	86	101	10	9	⅝in. 18in. W.G. 7ft. 6in. overall	2	Independent "Dual"
11	Distiller I...........			3,900	85	15·8	—	—	18	80	132	140	—	—	⅝in. 18in. W.G. 5ft. overall	4	Small Plunger Pump
12	Distiller II.........		—	860	7·8	110	Atmosphere	—	—	77	105	110	—	—	½in. 18in. W.G. 2ft. 6in. overall	1	—
13	Turbo-Generator condenser.		—	15,000	300	50	—	—	23½	60	111	120	—	—	⅝in. 18in. W.G. 5ft. overall	4	"Monotype"

not will depend on whether the transmission rate is affected by the state—liquid or gaseous—of the material on the steam side of the tubes, always remembering that equal velocities are assumed. Careful experiment and the results of experience on a large number of installations have failed to reveal any reaction of this kind on the transmission rate. Practical considerations, however, which limit the closeness of pitch of tubes, prevent the attainment of high velocities with water except when held in suspension in a gaseous medium. One is accordingly led to the conclusion that, in a condenser of homogeneous construction, submerged tubes are not compatible with the highest overall efficiency.

To summarise, then: The steam path in a condenser should be straight and of decreasing cross-sectional area, and should contain no submerged surface.

Let the water path be now considered. As there is no change in volume of the water, and as its heat-transferring value, per unit temperature difference, is not appreciably changed during its course, its velocity, and hence the cross-sectional area of its path, should be uniform. The velocity chosen will depend on the mode of variation of the heat-transmission rate with velocity and on the permissible expenditure in obtaining that velocity. In considering the correct quantity of circulating water to use, it must be borne in mind that the quantity of water chosen will necessarily define its outlet temperature. The actual quantity will then be a matter of compromise between expenditure of pumping it, and its reaction on the length of water path required before the outlet temperature which it entails is attained. In actual practice, however, the mode of variation of those

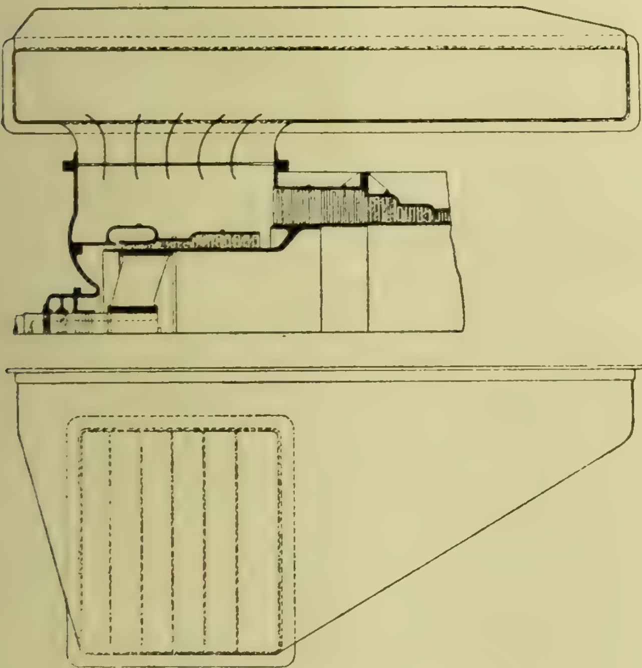


FIG. 4 EXHAUST BEND DIAGRAM.

factors makes the best compromise fairly obvious. A large number of outside circumstances may thus have to be taken into consideration before the correct water path is found, but their effect on the design of the condenser may, in every case, be readily seen from the above considerations.

Having thus deduced the principles of design, it now remains to demonstrate the mode of application of those principles to the experimental data in concrete cases. To take the water path first, the variation of heat-transmission rate with velocity of water flow is as shown in Fig. 1. The variation of frictional head with velocity (for the size of tube commonly used) is shown in Fig. 2. These values, in conjunction with circulating pump and engine efficiency, will enable the expenditure on circulating water to be contrasted with its heat-abstraction value.

In connection with Fig. 1, it must not be assumed that the rates indicated are in every sense absolute. Under certain favourable conditions much higher rates have been achieved, but the apparatus necessary is, to a certain extent, of abnormal proportions, and in practice such a condensing plant would not represent a satisfactory compromise. All condensing plants are to some extent influenced in their design by non-technical factors, and are correspondingly open to criticism by those ignorant of these factors.

Having thus briefly indicated the most important factors in surface-condenser design, reference to Table I. will show a number of examples typical of modern practice for widely varying conditions, together with the performances of these installations. One of the most interesting installations is No. 8, where economy in circulating water was necessary, and No. 9 is also exceptional as showing the performance of one of the installations with engine-driven "Dual" air pumps. No. 10 shows the overload performance on a turbine yacht where light weight of condensing plant was of great importance. In the case of the reciprocating-engine installations the vacua being carried are too high for economical running, but in every example the trials were made to show high degrees of vacua as being of interest in connection with the condenser performances apart from the main machinery. Installations Nos. 11 and 12 show the result of distiller trials, such apparatus being designed as condensers, and the performances are inserted for their comparative interest.

Fig. 3 shows three typical tube-plate diagrams showing how uniform velocity is attained by contour of shell and

TABLE II.—*Condenser Weights.*

Class of Installation.	Vacuum in inches.	Sea Temperature, Deg. Fah.	Material of Shell.	Type of Condenser.	Weight per H.P. in lbs.	Engines.	Assumed Stm. Consump. per H.P. in lbs.
Cargo steamer 3,000 h.p.	23	85	Cast Iron	Old Rectangular on engines	8·3	Reciprocating.	15
" " 3,000 h.p.	23	85	Steel	Circular	7·5	"	15
" " 3,000 h.p.	25	85	"	"Uniflux"	3·35	"	15
Cross-Channel boat	28·5	55	"	"	3·5	Turbine	14
Atlantic liner	28·5	60	"	"	4·67	"	14
Destroyer (1900)	26·5	55	Sheet Brass	Oval	2·7	"	16
" (1912)	28	55	Steel	"Uniflux"	2·1	"	14
Cruiser (1907)	27	55	Cast G.M.	Circular	4·4	"	15
" (1912)	28·25	55	Steel	"Uniflux"	3·4	"	14
Battle-ship (1906)	28·5	55	Cast G.M.	Circular	6·06	"	1[illegible]½
" (1912)	28½	55	Steel	"Uniflux"	4·09	"	13½
Distilling Condensers ..	18	80	"	"	2·2	"	15

varying pitch of tubes to suit special conditions of space. Table II. also gives some interesting figures regarding the weights of condensers.

As indicated, adherence to the principles of design enunciated in the foregoing results in a type of condenser wherein no attempt whatever is made to achieve what has been termed sectional or compartmental drainage, and as this is a feature for which many revolutionary claims have been made, it merits attention. In condensers possessing this feature, it is stated that the water of condensation is intercepted and removed to the hot-well as soon as it is formed—the basis idea being that the heat-transmission rate will thereby be improved and the hot-well temperature increased for a given vacuum. So far as experiments carried out by my firm have shown, no influence on the transmission rate by the interception of this water can be traced, while the claim for higher hot-well temperature is, I think, no longer supported. The most interesting feature of this question concerns the means employed to achieve the sectional or compartmental drainage, and consideration of this involves knowledge of one of the rudimentary phenomena which exist in surface condensers. Necessarily, the carrying out of this drainage feature includes the subdivision of the condenser by baffle-plates or collectors lying approximately parallel to the steam path, the angle of deflection presumably representing the extent to which gravity is to assist in the interception and removal of the condensed water. Now the velocity of steam flow in a high-vacuum condenser might be taken as 500ft. per second, which represents 340 miles per hour, and consideration of this simple statement explains the fallacy of sectional drainage, together with the impossibility of its practical achievement. Another misconception with reference to condenser design concerns the use of what might be termed an inverted condenser, *i.e.*, one in which the steam admission is at the bottom and the air extraction at the top. It has been stated that in such a condenser the steam will not readily rise, but, as a matter of fact, the steam will rise with the velocity already indicated, and if

space considerations permitted the adoption of such condensers, their performance would be quite as good as that of existing installations.

Before leaving this subject it is necessary to point out the extreme difficulty, at present, of accurately recording high degrees of vacua. In the first place, this is due to the almost invariable inconsistencies of the ordinary types of vacuum gauge; and secondly, to the effect of the high velocity of the steam in the exhaust pipe affecting the readings. These velocity considerations also demand that careful attention should be given to the design of abnormal shapes of exhaust bends. Fig. 4 shows an example of one means of counteracting the tendency of the steam issuing from the turbine blades to maintain its direction of flow, and in condensers with separate compartments to cause unequal distribution. The provision of directing blades in the exhaust branch gives the necessary direction to the steam without actually subdividing the exhaust pipe from the turbine to the condenser.

(*To be continued.*)

SOURCES OF ENERGY AVAILABLE FOR POWER.*

BY DR. H. S. HELE-SHAW, F.R.S., M.INST.C.E., M.I.M.E.

I ASK you to consider a wide, but, I hope, interesting, aspect of power, viz., the available sources from which it can be derived. For very cogent reasons this matter is attracting more and more attention. It may be worth while to summarise what are really our available sources of power, and to state one or two conclusions as to economies which are possible. Lord Kelvin, some 30 years ago at the British Association, summarised the stores of energy as follows: (1) The food of animals; (2) natural heat; (3) solid matter found in elevated positions; (4) the natural motions of water and air; (5) natural combustibles (as wood, coal gas, oils, marsh gas, diamond, native sulphur, native metals, meteoric iron); (6) artificial combustibles (as smelted or electrically deposited metals, hydrogen, phosphorus). Which list boils down into three divisions, viz.: (1) Heat radiated from the sun (which is either directly or indirectly the source of power of animal effort), of water power by wheels, rivers, steam engine, windmills, and the power of wind; (2) the motions of the earth, moon, and sun, giving tidal effects; and (3) terrestrial or meteoric sources of energy, such as hot springs, native sulphur, or the heat of newly-fallen meteoric bodies; which, summed up, he expressed as represented by tides, food, fuel, wind, and rain. Taking these sources of power as used in this country, we will consider them in the following order: (1) The coal problem; (2) the liquid fuel supply in the form of mineral oils and petrol, and of any possible vegetable substitutes for these; (3) water and wind power; (4) certain suggested sources of energy, such as the internal heat of the earth and the possibilities of radium.

(1) **The Coal Supply.**—The Royal Commission on this subject, in their report, estimate that there are in round numbers one hundred thousand million tons in our known coalfields in the United Kingdom. The present annual output is about 230,000,000 tons. The rate of increase is about $2\frac{1}{2}$ per cent. per annum, but the Commissioners consider that this rate is not likely to continue; but that, with the exhaustion of the shallower collieries, the output will gradually become slower, followed by a stationary period, and then by a decline. Assuming the present rate of output to be maintained, our coal resources would last more than 400 years; but, of course, long before that time, even supposing fresh coalfields to be discovered, the price would rise enormously, and, whatever other source of power was available, this would modify the conditions of existence, quite apart from seriously crippling our industries. More than two-thirds of the coal used in this country is for engineering and manufacturing, the remainder for domestic purposes. Dr. Beilby gives an estimate as to the possible economies and the amount of coal actually used. Of the total 171 million tons actually used he estimates there is a possible saving of $47\frac{1}{2}$ million tons. Dr. Beilby points out that a great saving might be effected by the use of recovery ovens instead of beehive ovens in coking coal, and that a fair indication of what is going on in this direction is the increase in the annual production of sulphate of ammonia in coking—from 17,400 tons in 1903 to nearly 83,000 tons in 1909. Dr. Beilby remarks: "If the present increasing rate of conversion is continued, within the next few years the greater part of the 16,000,000 to 18,000,000 tons will be turned into coke in this way, and a saving of 2,000,000 to 3,000,000 tons of fuel accomplished." This is only one kind of saving that might be effected. Prof. Vivian Lewes points out that the rapid advance made by gas as a fuel in stoves, cookers, &c., has reduced the consumption of coal for domestic purposes, and that if the whole of our fuel could have the smoke-forming tar and fertilising nitrogen extracted at the gasworks, it would mean a great economy and also a cleansing of town air.

The progress in the use of gas engines has been extraordinary; but before discussing it, it might be well to consider possibilities of improvement in the steam engine itself. To the steam turbine we owe a considerable advance towards possible limits of thermal efficiency of the steam engine. The Hon. Sir Charles Parsons states that the upper limit of temperature to which working is possible has been nearly reached, and remarks: "The highest efficiency realised by any steam engine up to the present is about $12\frac{1}{2}$lbs. of steam per kilowatt-hour, equivalent to 9lbs. per shaft horse-power, or a little over 1lb. of good coal, or about ·85lb. of oil burnt under a good boiler. This result has been obtained with units of 10,000 h.p. working at full load, with a steam pressure of 200lbs. gauge, superheated to a temperature of 300° C., and exhausting into a vacuum of 1in. (absolute) of mercury. It represents a conversion of about 70 per cent. of the available energy of the steam into mechanical power, or a conversion of about one-fifth of the heat in the fuel into mechanical work." His final conclusions are: "In practice, a temperature is soon reached beyond which the increased deterioration of the superheater boiler and engines more than counterbalance the saving in fuel, so *that finality in this direction is soon reached, and, in fact, has already been nearly approached.* At the lower end of the cycle the temperature of the condenser being determined by that of the circulating water, there is not much scope for improvement. There is, however, a probability of improvement in boiler and engine efficiencies by reduction of petty losses, which in the aggregate represent a loss nearly equal to the total energy realised as mechanical work. These losses are about equally divided between the boiler and the engine, and have for many years been the subject of much careful thought and investigation. The conclusion at present appears to be that the boiler and the steam engine may be improved by improvements in combustion, in the efficiency of heat transfer in the boiler and superheater to the working fluid, and in the engine itself, *but that no further substantial improvement is possible in the condenser.*"

Coming next to the internal-combustion engine, Dr. Dugald Clerk remarks: "It is possible in a large gas engine to increase the indicated thermal efficiency to about 50 per cent., but in such an engine the mechanical efficiency obtained would be about 40 per cent. The smaller gas engines do not give quite such good results, but the falling off is not great." Dr. Clerk further remarks: "A large amount of power can still be obtained from the blastfurnace gases evolved at ironworks. Assuming 10,000,000 tons of pig iron to be made in Britain per annum, and allowing for the free gas available after heating the blast, about 700,000 h.p. could be continuously developed *without burning any additional fuel.* Some of this gas is used for motive power, but the greater part of it is wasted. The gases evolved in coking processes can be collected and used for motive power. From this source it is possible to obtain about 140,000 h.p. continuously. Engineers are engaged in attempting to use all sources of motive power, and at no time have they paid greater attention to waste gases and waste heat than at present. The waste heat carried away in the exhaust gases of gas engines is utilised in many cases for raising steam, and about $2\frac{1}{2}$lbs. of steam at over 100lbs. per square inch pressure can be obtained per hour per brake-horse-power. The exhaust steam, too, from rolling mill engines and other engines using little expansion is being applied to operate low-pressure steam turbines. Practically all the waste heat from gas engines,

* Abstract of presidential address delivered before the Association of Engineers-in-Charge.

amounting to about 50 per cent. of the total heat of combustion, could be used in some such manner." Dr. Clerk concludes: "It is evident that if steam power could be entirely replaced by power obtained by internal-combustion the fuel consumed would be reduced one-half. It may be asked, then, by scientific men, Why not legislate so as to enforce the use of gas power? Apart from the varied monetary interests which would make it impossible to carry any such law, the law, even if carried, would be of most doubtful benefit. Great industrial inventions cannot be perfected in a few years, and any attempt to force the rate of progress usually ends in financial disasters which discredit the rising industry. The monetary reward of successful competition with steam is so great that engineers may be trusted to forward the application of the new form of motive power."

(2) **Mineral Oils and Spirit and their Substitute.**—Considering next the available supplies of petroleum and petrol for use as motive power, we have a summary, given by Sir Boverton Redwood, of the whole output, in which the quantity produced per annum all over the world is put down as approximately 38,000,000 tons. Sir Boverton Redwood remarks: "If the whole of this crude petroleum were employed as fuel in steam raising, it would not replace, allowing for its higher thermal efficiency, much more than 5 per cent. of the world's output of coal; whilst, if used in internal-combustion engines, it would be equivalent, as a source of power, to about 15 per cent. of the coal. Only a small proportion, however, of the crude petroleum can be regarded as available for use as a source of power, for by far the larger part is in demand as an illuminating agent and as a lubricant for machinery." His conclusions are that "it is not probable that there can be any general substitution of petroleum for coal as a source of power, although there is undoubtedly opportunity for making provision for a larger use of liquid fuel for certain selected purposes in which its advantages are conspicuous, especially in ships of war."

In a report of the committee of the Motor Union, the subject of the possible substitutes for mineral oil and petrol spirit from vegetation were considered, although, owing to the convenient nature of petrol spirit in actual use and the price at which it can at present be obtained, alcohol is not largely produced for use for fuel purposes. The committee, however, owing to the rise in the price of petrol and the small probability of the price dropping again to the previous low figure, came to the following conclusion: "That there can be no possible doubt that alcohol might be made commercially successful in competition with petrol were the Excise restrictions less prohibitive." And the committee further stated that owing to the great strictness of the Excise authority, the process of dematuring, &c., brings the total cost of alcohol up to a price which may be very materially reduced, and that if this were so, alcohol would prove a serious competitor with petrol. The destruction of timber all over the world has practically put the use of wood as a fuel out of consideration, and although the Governments in various countries are systematically spending large sums on afforestation—Germany and France, for instance, are spending between them more than £2,000,000 annually—it is unlikely that timber will ever compete with coal or petroleum as fuel, considering the modern requirements in the direction of power. The chief use of timber will in the future not be for fuel, but for purposes of construction, and its cultivation will be promoted for its effect upon the rainfall of the country.

(3) **Water and Wind Power.**—As Mr. W. F. Reid remarks, two centuries ago nearly the whole of the mechanical power utilised in Great Britain was derived from wind and water: the total power derived to-day from these sources in this country is comparatively insignificant. There is a good deal of popular misconception on the subject of such power. It is generally assumed that the power of both wind and water costs practically nothing. Quite apart, however, from the rental of the necessary land, the upkeep of wind and water mills is by no means a negligible quantity; but the really unsatisfactory feature of such power is its uncertainty and intermittent character. The familiar sight of tall chimney stacks in secluded valleys in this country where paper, cloth, or cotton mills were placed many years ago, in order to take advantage of the local water power, and the fact that steam plant is an accessory of so many modern installations of water-power in other countries, shows that it is cheaper to duplicate the motive power plant, and use fuel as an alternative when water is not available, than to allow the valuable concern to stand idle. The storage of water in this country, made possible by its great waterworks, is largely for domestic purposes, and, even if this were not the case, a simple calculation shows the comparatively small amount available for power from the rainfall. In this matter, I am afraid I cannot agree with Mr. Reid when he says that, even if we do not get our share of the direct rays of the sun, yet indirectly we receive our full proportion of the energy derived from that source. Taking his estimate for that small part of the country where the rainfall exceeds 60in. per annum, and that 1in. of rain per acre is equivalent to 100 tons of rainfall, this only amounts to 6,000 tons per annum per acre, and, assuming an available fall of 400ft., this would give an actual working horse-power for 300 days in the year and 10 hours in the day of 1 h.p. per acre; whereas the radiant energy received by the earth in favourable localities may be estimated as at least 10,000 h.p. per acre—that is to say, 10,000 times as much. We shall, however, no doubt, agree with Mr. Reid that a good deal might be done to conserve the water power now running to waste in this country; although, even if this is done, we cannot ever hope to derive power from this source with an effect such as may be witnessed in other countries, where such storage, in conjunction with a suitable transmission, has been a source of great wealth in the promotion of industries in such countries as Italy, Switzerland, and Sweden, or even on a still larger scale on the American continent.

There is, of course, the other source of water-power, viz., the tides. Prof. Marshall, in his fascinating "Economics in Industry," gives a calculation, based on the rental of 10s. an acre, and an average rise and fall of the tide, which proves that at present tidal power cannot compare with steam power, even putting the cost of coal against the rental of the necessary land—that is, of course, in this country. Dr. Louis Bell, a few years ago, discussed this question in "Cassier's Magazine," and, taking as an illustration, the problem of the possibilities of the 40ft. tides in the Bay of Fundy, showed that for two runs of five hours each, more than 50,000 h.p. were available per square mile of reservoir, and that if the area between two headlands—three miles apart (an area of 400 square miles)—could be converted into a tidal basin, more than 20,000,000 h.p. would be available per day; but he pertinently remarks that to utilise it would require an engineering feat more tremendous than anything yet attempted by man. These figures, however, are interesting, at anyrate as showing there are sources of power which, in the event of the exhaustion of our fuel supply, may at some future date have to be utilised, though the conditions generally involved appear to make the probabilities of such use not likely to occur until centuries have elapsed. There are, of course, other ways of using tidal power, such as taking the power from a floating ship, but a simple calculation is enough to show the unpractical nature of such a scheme. Let us suppose a vessel of 1,000 tons, moored in a river where the tide rises and falls an average of 20ft. This would give an average working horse-power for 24 hours' continuous effort something like 2 h.p. Still less hopeful is the task of extracting power from a tidal mill in which the flow of the tide turns the paddles by the surface action. Such contrivances are to be seen in the floating baths on the Rhine and other rivers where the use of the water power is really for pumping, the action being similar to that of the earliest irrigation watermills of the East.

Concerning the action of the wind, as Lord Kelvin remarked many years ago, a considerable proportion of the ships of the world are still propelled by wind power, and there are, of course, an enormous number of windmills scattered over the surface of the world. Yet it takes a fairly large windmill to produce any reasonable effect. For instance,

in an example given by Weisbach, a windmill with four sails, each 24ft. long and from 6ft. to 9ft. broad, making 16 revs. per minute, and actuated by a fairly good wind, having a velocity of 20ft. per second, has as its highest theoretical effect only about 5 h.p.—that is to say, a windmill of this size would only produce the effect of a steam engine using from 10lbs. to 15lbs. of coal per hour, or a total in a week of 10 hours per day somewhere about 5 cwts. The coal in question would only cost from 3s. to 4s., and the steam engine would have the enormous advantage of uniformity of effect, and this with a continuity of action which cannot be ensured in the employment of the wind.

In conclusion, let us consider what other possibilities there are, and take first the direct heat of the sun's rays. In countries like California, where the sunlight is continuous and rain occurs practically only at night, the direct rays of the sun (as already remarked) may be considered to represent something like 10,000 h.p. available through at least eight hours of the day. The first attempt that we know of to employ this heat for actual motive power was by the great Swedish inventor, Ericsson, who, in this, as in other respects, was quite in advance of his time. The method of Ericsson was to concentrate the rays of the sun by a large number of reflectors upon a boiler, and to employ both a steam engine and the hot-air engine of his own invention. Dr. Louis Bell, in "Cassier's Magazine," gives an account of a recent type of such apparatus. The mirror construction takes the form of the frustrum of a short, hollow cone, with its base turned towards the sun. The base of the cone is 36ft. diam., with strips of silvered glass, 2ft. long, 6in. or 8in. in depth, carried in a light steel framework, the whole being carried on a polar axis, capable of being moved so as to follow the motion of the sun. The boiler is of coiled water pipe, constructed of 1in. blackened copper pipe, placed axially in the centre of the mirror; the mirror is 36ft. diam., and contains 1,000 sq. ft. of reflecting surface. The boiler gives 200lbs. pressure in full sunshine, and develops 10 h.p. The annual expense of this contrivance works out at about £15 per horsepower per year, which, as Dr. Bell remarks, is considerably below the cost of the power obtained from small steam or oil engines, and compares favourably with the price of electric power, at anyrate in small units. Ericsson estimated that nearly 10,000,000 square miles of the earth's surface were available for solar power, and that by this means the deserts of the world could be reclaimed by irrigation, thereby enabling the whole population of the earth to be supported. Dr. Louis Bell himself seems to contemplate at some future date a general migration of the population of the world, when fuel supplies are exhausted, to the warmer regions, where the conditions of life are not so severe and where such solar power would be available. It is obvious, however, that the solar power, from an engineer's point of view, is not a particularly hopeful solution of the power problem for inhabitants of the British Isles, and from our recent summer's experiences, it is fortunate that our manufacturers and industries do not depend upon this particular source of energy.

(4) **Heat derived from the Earth itself.**—With regard to the available heat of the earth itself as energy, the possibilities are well summarised by the Hon. R. J. Strutt under three heads: (1) The hot springs from the interior of the earth; (2) the streams of molten lava which flow from the interior almost perpetually, as at Stromboli; and (3) the possibility of pumping water to the heated interior, and receiving it back at a high temperature. Hot springs may be dismissed at once as giving too small a supply of heat, and, Mr. Strutt remarks, the opportunities of obtaining heat from molten lava are scarcely extensive enough to encourage inventors, and he somewhat quaintly summarised the possibility of the last method as follows: "If any attempt to supply such methods was made, it would be essential to begin at a volcanic crater, for the feasibility of reaching a zone of molten rock in other places is doubtful, even if such exists. The engineering difficulties of making the attempt, even when the molten rock is accessible, would be very great. Upon the whole it seems to me altogether unlikely that the problem raised by the prospective failure of the coal supply will find its solution in the use of underground heat." There is one more source of energy, depending on what Sir William Ramsay calls "atomic transformation," in which he is, of course, alluding to that marvellous substance, radium. According to Sir William Ramsay, a ton of radium gives off energy which in the course of a year would be equivalent to the burning of 117 tons of coal. In doing this, it suffers only a minute loss of its weight. In fact, it appears as if it would continue to exert this energy for something like 3,500 years; at anyrate, it would give out energy for apparently this time before it was exhausted—that is to say, a ton of radium would have evolved 460,000 times as much heat as an equal weight of coal. But, alas, there are several serious drawbacks to the bright hopes at first raised by such stored up energy. In the first place, I am not aware that anyone has suggested up to the present any practical means of actually converting this energy into mechanical effort for engineering purposes. In the second place, radium would, it appears, take between 3,000 and 4,000 years to develop all its power, so that its operation is only equivalent to the actual thermal effect per annum of 117 times its weight in coal. But, alas, there is yet the greatest drawback of all. Sir W. Ramsay estimates that, as far as can be reasonably conjectured, the whole world contains something like 5 cwt. of radium, so that if all the radium were available for power, and that power could be actually employed, this would only be equivalent to an annual supply of between 40 and 50 tons of coal per annum—that is to say, only about one three-millionth part of the actual coal which is consumed every year in this country alone.

I must now bring our review of our sources of power to a close, and it is evident that it is our coal supply which is the real source upon which we depend for mechanical power in this country, and although it will be beyond our time and that of many generations of our successors before our coal supply begins to show signs of exhaustion, yet the thought must strike each one that it is a duty incumbent upon us all to economise as far as possible the stores of coal in the earth. There is no one who does not feel that the reckless manner in which our predecessors have been allowed to denude this and other countries of timber is an evil thing; but the manner in which much coal is now wasted is just as evil a thing as the destruction of our timber supplies, with the additional evil that the wasted coal is a source of dirt and fog, with all their accompanying evils. We may not go as far as Dr. Louis Bell, who remarks that we of the present day have used our coal supplies like reckless vandals, robbing our children and our children's children without scruple. He even goes on to say: "There is no stopping the greedy hordes in their frantic money hunt, but it is part of wisdom to cast about for some means of saving the general disaster as much as possible." Ex-President Roosevelt puts the matter in the following words: "As a people we have the right and the duty to protect ourselves and our children against the wasteful development of our natural resources or by making them impossible of development hereafter." Sir W. Ramsay, in summarising the report of the British Science Guild, refers to a strong feeling that something ought to be done to preserve the continuity of the Royal Commission on coal supply, even if we agree with Dr. Dugald Clerk that actual legislation in the way of introducing greater economy would be undesirable. As Sir W. Ramsay remarks, this in no way precludes the establishment of a permanent body, whose duty it would be to keep the nation informed, through annual reports, of the actual state of our sources of energy, and the methods by which economies might be effected.

Institution of Engineers and Shipbuilders in Scotland.—The following awards of premiums for papers read have been made by the Council of this Institution: To Dr. T. J. Nicolson, for his paper on "Boiler Economics and the Use of High Gas Speeds," £5. 5s.; to Mr. T. B. Mackenzie, for his paper on "Means for Economising Fuel and Utilising Waste Heat in Malleable Iron and Steel Works," £3. 3s.; to Messrs. R. Royds, M.Sc., and J. W. Campbell, M.Sc., for their paper on "The Possibilities of Flue Gas Economisers on Board Ship," £3. 3s. each; to Mr. E. M. Speakman, for his paper on "The Wider Adoption and Standardisation of Water Tube Boilers," £3. 3s.; and to Mr. D. M. Shannon, for his paper on "Some Aspects of Diesel Engine Design," £3. 3s.

INTERNATIONAL ENGINEERING AND MACHINERY EXHIBITION, OLYMPIA.—IV.

Messrs. Samuel Platt, Ltd., of King's Hill Foundry, Wednesbury, exhibited several machines of their manufacture for forging and finishing nuts and bolts, as well as various types of screwing machines, bar reeling and straightening machines, and double-ended cutting-out and stripping presses. One of the screwing machines shown is for use with wrought or malleable iron, steam, gas, water, and conduit fittings. Three ways can be screwed simultaneously, after which the machine

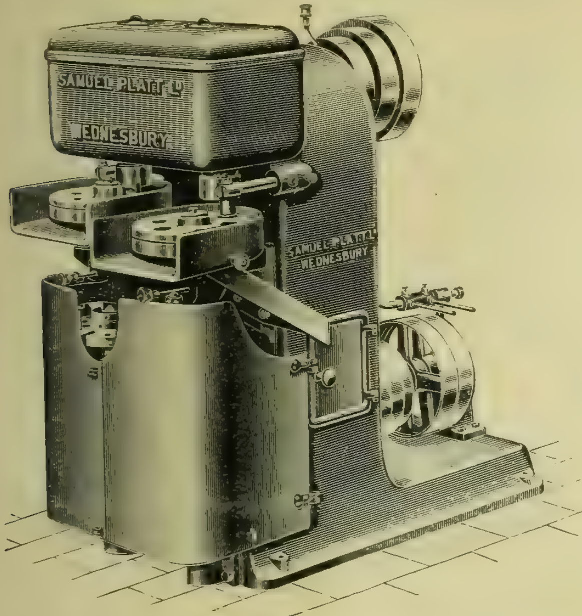


FIG. 1.—DOUBLE-SPINDLE NUT FRAZING MACHINE. MESSRS. SAMUEL PLATT, LTD., WEDNESBURY.

automatically reverses at quick speed and then stops, when the fitting is removed and the operation is repeated. Three of the nut-finishing machines shown are illustrated in Figs. 1, 2, and 3. Fig. 1 is a double-spindle nut frazing machine which is semi-automatic in action, the nuts being placed in chucks on the revolving tables, when they are automatically frazed and ejected. The output is therefore regulated by the operator's dexterity in feeding the machines. Nuts of varying thickness can be frazed, as a wide range of adjustment is provided, and all gears have machine-cut teeth.

Fig. 2 is a self-contained 4-spindle nut-tapping machine, the illustration of which is almost self-explanatory. We may

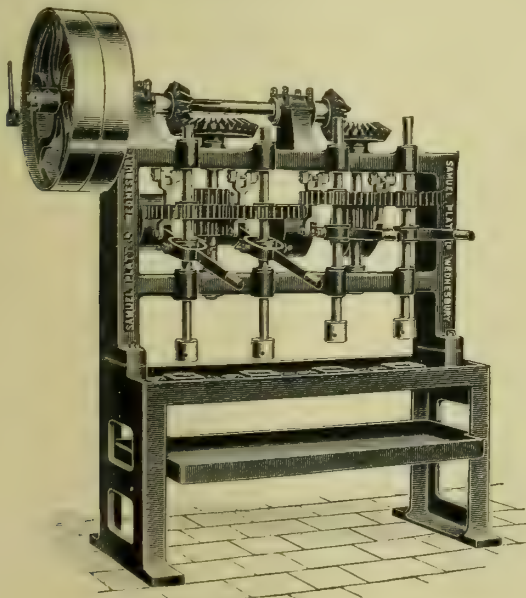


FIG. 2.—4-SPINDLE NUT-TAPPING MACHINE. MESSRS. SAMUEL PLATT, LTD., WEDNESBURY.

mention, however, that the spindles of these machines can be arranged to run at the same speed, or two of them may be made to run faster.

Fig. 3 is a nut-facing and chamfering machine. In this machine nuts are faced absolutely true with the thread, and gauge stops can be set to give any thickness required. After facing, the nuts are automatically removed without stopping the machine.

Messrs. The Britannia Foundry Company, of Cox Street, Coventry, and **The Adjustable Moulding Machine Company,** of West Orchard Works, Coventry, had a joint exhibit on Stand No. 79 of moulding machines, sand-mixing machines, enamelling stoves, and other foundry requisites, in the manufacture of which they have specialised. Two of the exhibited machines we have pleasure in illustrating in Figs. 4 and 5, Fig. 4 being the "Coventry" moulding machine No. 2 and Fig. 5 the adjustable moulding machine. The latter machine, as will be seen, consists of a single column, or pedestal, on which are mounted two fixed arms similar to a lathe V bed; upon these arms are two sliding columns which carry the moulding boxes, and can be instantly moved to take any size pattern plate from 8in. to 24in. wide, length unlimited, and locked in any position by an eccentric. These columns are in turn fitted with rests for carrying the moulding boxes, which can be adjusted to suit any different thicknesses and makes of pattern plates. The pattern plates are fixed directly or indirectly on a table, in the centre of which is a strong plunger, which supports the plate in a proper manner and

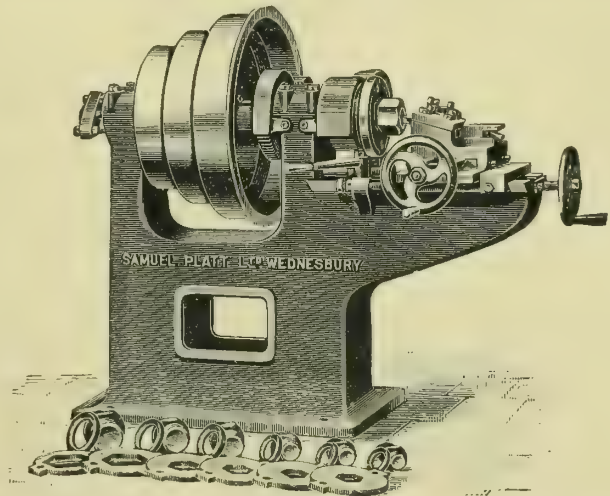


FIG. 3.—NUT-FACING AND CHAMFERING MACHINE. MESSRS. SAMUEL PLATT, LTD., WEDNESBURY.

takes all the pressure of the ramming. The plunger is operated from below with a crank and central thrust connecting rod, which enables the pattern to be drawn from the mould in a perfectly true, smooth, and accurate manner. All the working parts are accurately machined and, being enclosed, are entirely protected from any evil effects of the foundry sand. This machine only draws the patterns, the ramming of the mould being done by hand, but as the patterns are drawn absolutely accurate a great amount of time is saved in sleeking, patching, and mending the moulds.

The "Coventry" moulding machine shown in Fig. 4 will, it is claimed, mould any casting, however intricate, that can be moulded on any other known machine (providing it is not too large to go on the table), and the firm claim that its depth of ram and height of lift are greater than any other moulding machine on the market. It is a power machine without power, *i.e.*, patent mechanical gear in the head enables a man, without undue exertion, to ram any mould as hard as it is required, and so does away with the expense of hydraulic or pneumatic power. The ram works with a squeezing motion, and thus the operator can easily gauge the amount of pressure. The lift is also perfectly steady, true, and parallel, and not only lifts moulds off the pattern, but moulding box off the table pins.

Messrs. Frederick Pollard & Co., Ltd, of St. Saviour's Road East, Leicester, exhibited a collection of their "Corona" drilling machines, in which class of tool they have specialised, and about one-half of these were shown running. They ranged in size from a 12in. bench drill to a 24in. upright high-speed machine, many of them being equipped throughout with ball

bearings. The advantages of ball bearings for high speed drilling of small holes are many. By their use drills may be run at the highest speed they are capable of efficiently holding up to, and as the friction of bearings is at a minimum, practically the whole of the driving power utilised is used to revolve the drills. A great saving in power is thereby effected, and the maximum output obtained from machine and drills. Another important point is that the bearings are practically indestructible and do not require the same attention as regards lubrication, greasing once a year being all that is necessary to keep them in good condition. All "Corona" sensitive drill spindles, we are informed, are fitted with ball journal and thrust bearings, and all new models can be supplied equipped throughout with ball bearings (including loose pulleys). When so fitted, the spindles are bored with a size larger Morse taper, and machines may be run 50 per cent. faster than the speed specified for plain bearing machines. In some recent tests at the "Corona" Works, with new model 13in. and 15in. sensitive drills, a number of holes ½in. diam.

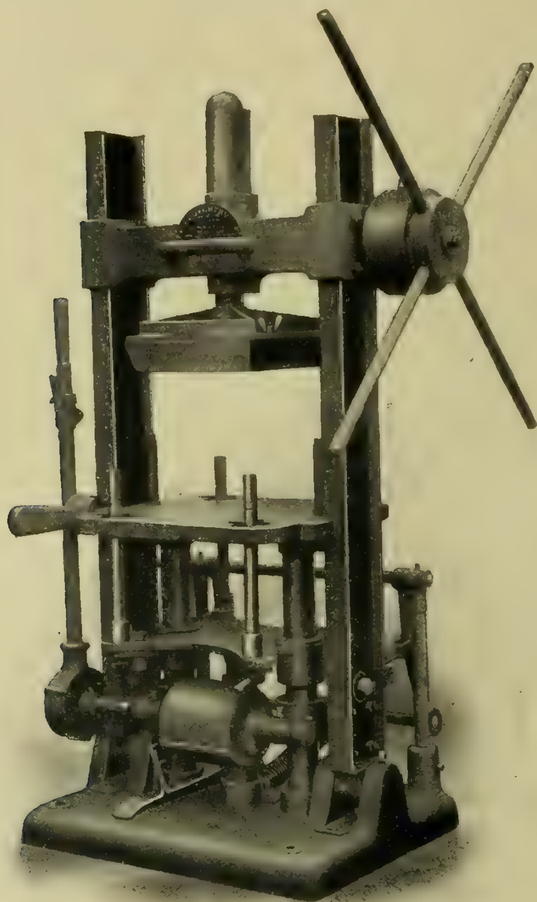


FIG. 4.—"COVENTRY" MOULDING MACHINE. MESSRS. THE BRITANNIA FOUNDRY CO., COVENTRY.

and 1in. deep were drilled in ordinary cast iron in two seconds each, also a number of ¾in. holes of same depth and in same material were drilled in four seconds each.

It is obviously impossible in the limited space at our disposal to describe all the machines shown by the firm, but the one illustrated in Fig. 6 may be taken as fairly representative of their manufacture. This is their 20in. new model "Standard" drilling machine, single geared and having positive automatic feed. This machine will, we understand, deal with all classes of material up to 1¼in. diam. All shafts, spindle, &c., are made from the solid, and are turned and ground. The bearings are of the ring oil type made from C.I. and are renewable. The rack bush is made from steel with teeth cut from the solid, and is graduated and fitted with gunmetal bushes. All the gears, as will be seen, are guarded, and all levers are made from malleable iron. The table, which is of large diameter, is raised by a steel worm and gunmetal worm wheel operating a steel pinion, which in turn gears with the cut rack on the side of the standard. The drill spindles are all fitted with Hoffmann ball thrust, and the feeds are positively operated by lever and feed worm, which is always in gear.

Messrs. Perkin & Co., Ltd., of Whitehall Road, Leeds, exhibited on Stand No. 3 a representative collection of machine



FIG. 5.—ADJUSTABLE MOULDING MACHINE. MESSRS. THE BRITANNIA MOULDING MACHINE CO., COVENTRY.

tools of their manufacture, including lathes, shaping, grinding, drilling, and hacksawing machines. Many of these, however, we have previously described, so we purpose confining our remarks to a short description of two lathes on which several new features have been introduced. Fig. 7 shows the 8½in. centre by 8ft. bed Anglo-American type lathe exhibited,

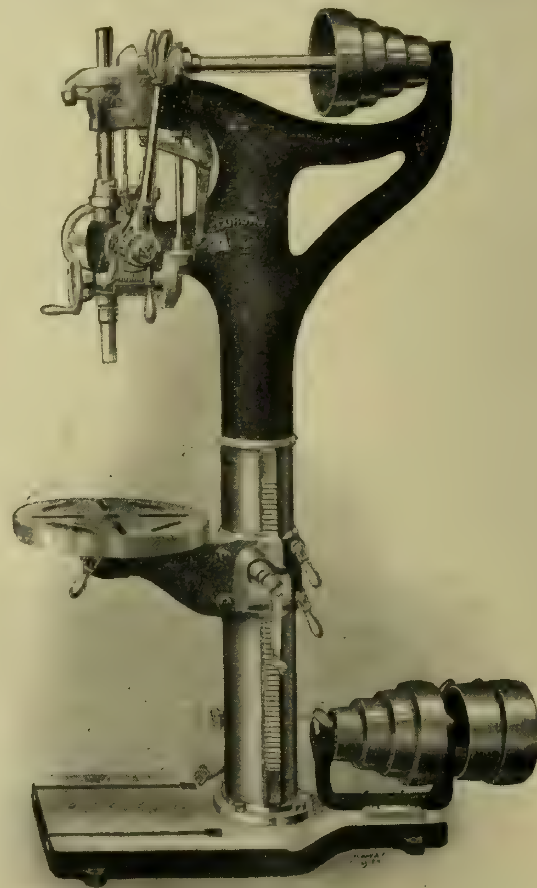


FIG. 6.—"CORONA" 20IN. UPRIGHT DRILLING MACHINE. MESSRS. FREDERICK POLLARD & CO., LTD., LEICESTER.

On the front of this machine, as will be seen, a bar is fitted immediately below the apron and this carries a number of automatic stops for the longitudinal feed. Any number of stops can be used, and for each and every automatic stop a dead stop is also provided. Messrs. Perkin inform us that it is possible on this machine to duplicate lengths exactly. For the cross traverse a new stop motion is used, which is entirely novel in design, and for which letters patent have been taken. Messrs. Perkin claim that with this stop motion after once setting the tool to the first diameter to be machined any number of identical pieces can be turned, with the confidence that they will be quite uniform, and the rate at which the machine operates upon bar work, armature work, spindles, &c., is surprising. Other principal features of the machine are, that it has a semi all-gear head giving five speeds without moving the belt, four ratios of double gear, and two countershaft speeds giving 20 spindle speeds in all; all the motions are controlled without the use of spanners, and the four positive feeds can be instantly obtained; the feed motion in the apron is also positive, and therefore there is no tendency to slip; and the feeds are independent of the screwcutting and are interlocking.

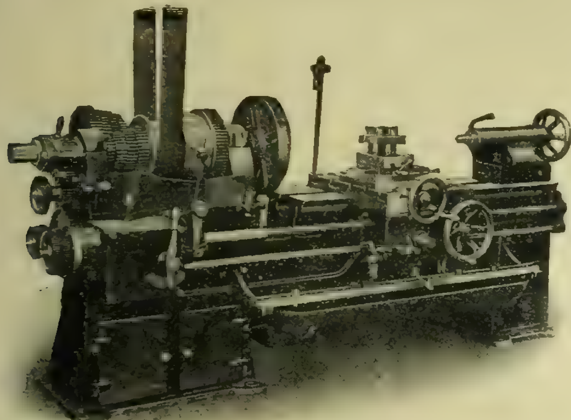


FIG. 7.—8½IN. CENTRE ANGLO-AMERICAN TYPE LATHE. MESSRS. PERKIN AND CO., LTD., LEEDS.

On the 7½in. lathe, which we regret we are unable to illustrate, they have introduced as a new feature a positive interlocking feed for the sliding, surfacing, and screwcutting motions. All the motions in this lathe can be engaged or disengaged without the use of a spanner, each and every one being readily obtained, and it is impossible for any two of them to be engaged at the same time. Messrs. Perkin & Co. inform us that so far as they are aware this is the only purely English type lathe which has this feature. The lathe has a 3-speed cone and two ratios of double gearing, giving nine spindle speeds, six of which are double geared, and all in geometrical progression, together with variable feed motion to the back shaft.

Messrs. H. W. Ward & Co., Ltd., of Lionel Street, Birmingham, had a very large stand and showed a representative selection of their well-known capstan and turret lathes, milling machines, and ball bearing drills, which we particularise below:—

Wire Feed Capstan Lathes.—4in. centre, ½in. patent wire feed capstan lathes, in operation making small brass oil caps. 5in. centre, ¾in. patent wire feed capstans, in operation making screws from bright drawn steel bars. 6½in. centre capstan lathe, fitted with their patent automatic chuck to take bars 1½in. diam.

The patented features of these lathes, in connection with the wire feed and automatic chuck, are worthy of special notice. The old-fashioned toggles are dispensed with, the chucks are easier to operate, have more latitude as regards variation in size of stock, and greater gripping power.

Friction Geared Capstan Lathes.—6½in. centre friction geared capstan lathe, with 1⅝in. patent automatic chuck and bar feed; this machine was shown in operation making sleeve clutches for feed boxes from steel bar. 7½in. centre friction geared capstan lathe, with 2⅛in. hole through spindle, automatic feed to capstan slide, and automatic chasing saddle.

This latter machine, which we have pleasure in illustrating in Fig. 8, was shown in operation machining 1¼in. globe valves, the three ways being machined at one setting by means of a revolving valve chuck.

Plain Chucking Lathe.—This machine was of entirely new design and would be interesting to motor engineers. It was much simpler than the combination turret lathe, and suitable for much work that has hitherto been done on more expensive machines. The headstock of this type lathe is 9in. centre and is fitted with duplex friction back gear, the main gear wheel being directly on the back of the chuck. There is also a 3⅝in. hole clear through the spindle. The saddle has automatic sliding and surfacing, and screwcutting motion with six stops in each direction. The apron mechanism is patented and is a great

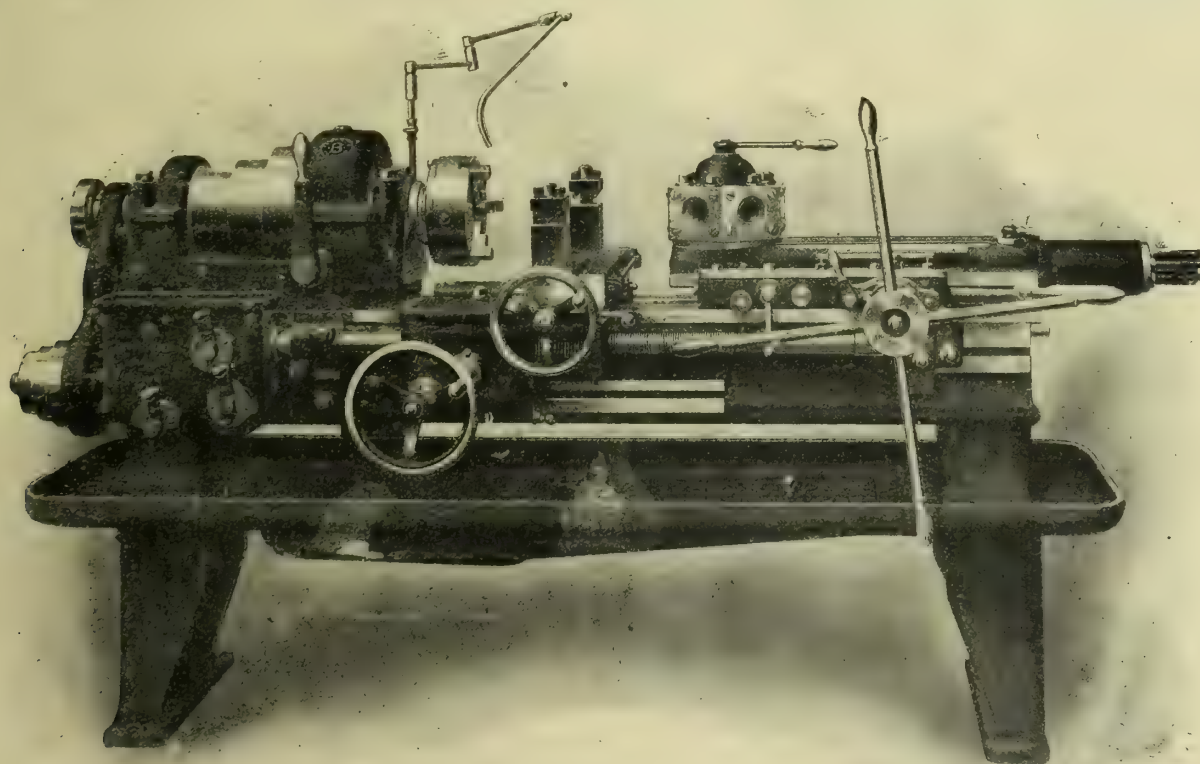


FIG. 8.—7½IN. CENTRE FRICTION-GEARED CAPSTAN LATHE. MESSRS. H. W. WARD & CO., LTD., BIRMINGHAM.

advance on the old types, only one handle being used for operating both the sliding and surfacing motions; this in connection with the one handle for the nut, and quick withdraw, makes only two handles to control the whole of the movements. It is, we should say, one of the simplest and most effective aprons yet on the market, and as every movement is interlocked it is impossible to cause damage through inefficient operating.

Combination Turret Lathe.—This type of lathe was represented by the largest size made by the firm. It swings 27in.



FIG. 9.—"COP" PLATE-LIFTING CLAMP IN ACTION. MESSRS. THE ALEXANDER MANUFACTURING CO., LTD., LONDON.

diam. and has a $6\frac{1}{4}$in. hole through the spindle. It was shown in operation on heavy forged steel gear blanks, &c.

Flat Turret Lathes.—Two sizes were exhibited, the smaller $1\frac{3}{4}$in. by 24in. and the larger $2\frac{1}{2}$in. by 30in., a still larger size being made to take $3\frac{1}{2}$in. by 42in. The smaller machine had not been exhibited before, and the larger one had only been re-designed recently. Both of these machines were shown in operation producing parts from mild steel.

Milling Machines.—Three sizes of horizontal machines were exhibited and one vertical machine. The horizontal machines are made in a full range of sizes, both plain and universal, and can, we understand, be supplied either with countershaft and cone pulley drive, or all-geared with single pulley drive. The machines are capable of taking exceptionally heavy cuts and were also shown in operation.

Ball Bearing Drills.—These are made in three sizes—either single spindle or multiple. Each of the sizes were represented and could be seen in operation; the No. 0 machine will drill up to $\frac{1}{2}$in., the No. 1 up to $\frac{7}{8}$in., and the No. 3 to $1\frac{3}{16}$in. clear in high speed steel.

Cutter Grinding Machines.—These machines, which are extremely handy tools, are made in two sizes, the smaller one only being exhibited. Like the others it, too, was shown in operation.

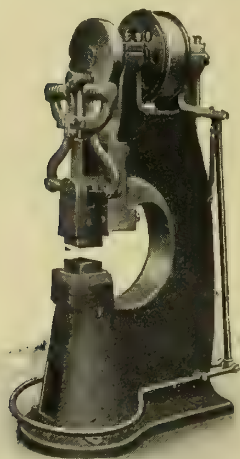


FIG. 10.—"GOLIATH" HAMMER. MESSRS. THE JUDSON-JACKSON CO., LONDON.

Messrs. The Alexander Manufacturing Company, Ltd., of 42 and 44, Moor Lane, London, exhibited a complete range of steam and water cocks and valves, together with a number of interesting sectional models to illustrate the interior construction. Small tools were also shown, as well as a few large screwing machines. The well-known "Mork" pulley block was also shown, a particular feature of which is the safe and reliable releasing gear, which allows of the bottom empty hook being rapidly raised or lowered and thus brought into position again immediately after discharging its load. An ingenious device for holding plates, exhibited by the firm, is illustrated in Fig. 9. This is known as the "Cop" plate lifting clamp, and, as will be seen, it is a very neat and effective tool for the purpose. Its action will be readily understood from the illustration, the small roller running down the inclined inner face of the jaw of the clamp and thus gripping the plate.

Messrs. The Judson-Jackson Company, of 14, Great Smith Street, Westminster, exhibited some interesting machines in the shape of belt-driven forging hammers, all-gear high-speed lathes, and universal wood-grinding machines, and three of these we have pleasure in describing and illustrating herewith. Fig. 10 shows their "Goliath" hammer, having a ram of 60lbs. weight, and capable of dealing with iron up to 4in. As will be seen, the chief feature of these machines is the patent spiral spring crank plate connection, the only motion in existence, it is claimed, which gives a perfect whip stroke. The connection between the ram and crank pin also gives to the ram a balanced reciprocating motion, perfectly cushioned at each end of the stroke, and produces a thoroughly effective blow. The formed levers which transmit the motion are of forged steel, while the ram itself is of ample strength and runs in slides having means for taking up wear. The machine, which will deal 275 powerful blows per minute, is fitted with friction

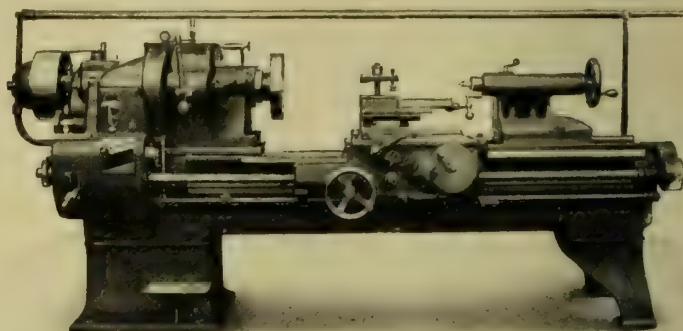


FIG. 11.—SCHAERER ALL-GEAR HIGH SPEED LATHE. MESSRS. THE JUDSON-JACKSON CO., LONDON.

pulley drive, and thus no countershaft is required. The pulley, which can be run in either direction, is provided with forced grease lubrication through the centre of the shaft from the rear, is operated by the foot lever, and fitted with automatic spring release. Thus the smith who holds the work can also operate the machine by means of his foot. A second hammer, known as the "Hercules," and having a ram of 160lbs., and capable of dealing with iron up to 6in., is also shown. This operates on exactly the same principle, but is naturally more massively built, the body being of box section and having a 7in. diam. hole through it immediately behind the anvil to facilitate the handling of long bars.

An all-gear lathe exhibited by Messrs. The Judson-Jackson Company is illustrated in Fig. 11. This is the newest design of the well-known firm of Schaerer & Co., of Karlsruhe, whose

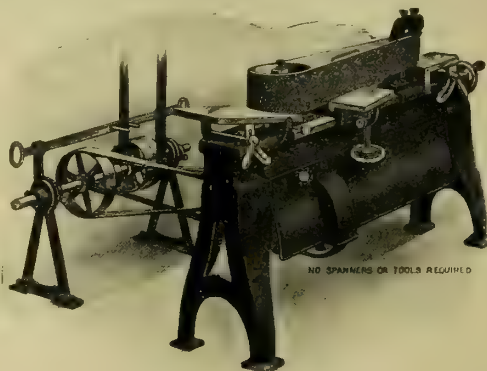


FIG. 12.—UNIVERSAL WOODGRINDING MACHINE. MESSRS. THE JUDSON-JACKSON CO., LONDON.

works are exclusively employed in the building of lathes. The bed, as will be seen, is of box section mounted on suitable standards, and a special feature is that the top of the bed is only used to carry the fast and loose headstocks. The saddle travels clear of the top, being carried by V slides cast on the back and front shears, and as these are cast at different heights, it eliminates any possibility of twist in the saddle. The lead screw and rack are situated between these points of support.

The all-gear headstock gives 20 spindle speeds, and any of these can be put into gear whilst the machine is running in

from one to three seconds, and it is impossible for two sets of gearing to be in at once. The lathe is driven through a constant-speed pulley, arranged with an internal friction clutch which is operated by the rod shown in the illustration, and conveniently placed over and behind the machine. The drive can thus be taken direct from the line shaft, or a constant-speed motor can be direct coupled by belt or chain. The driving pulley is bushed inside the back bearing in order to avoid any possibility of the shaft becoming sprung because of the belt pull. All the gears are hobbed on the generating principle to secure noiseless running, and the whole arrangement is "foolproof." Index and speed plates are fitted which enable the operator to read at a glance the cutting speed produced by any movement of the levers on any diameter of work.

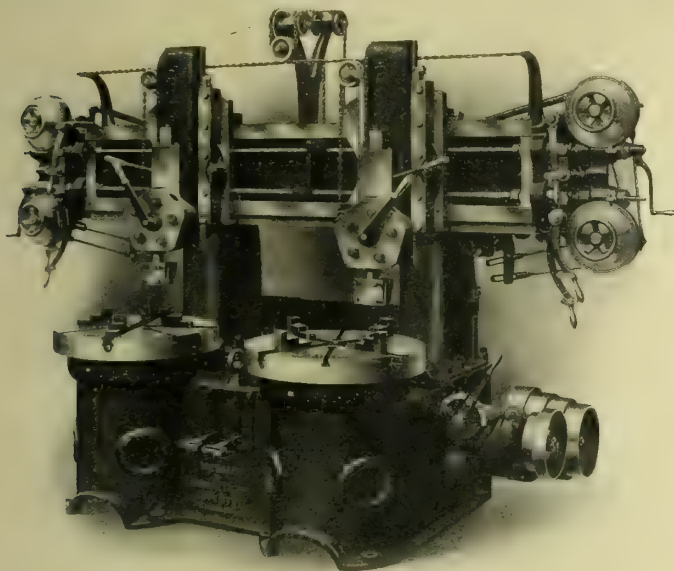


FIG. 13.—36IN. DUPLEX BORING AND TURNING MILL. MESSRS WEBSTER AND BENNETT, LTD., COVENTRY.

The spindle is hollow, and the drive, being applied as close as possible to the spindle neck, a downward pressure is there produced which counteracts the upward pressure of the tool on the work, the result being that heavier cuts may be taken with far less danger of excessive wear and tear. Another special feature is that the thrust of the spindle is taken on a ball race direct at the front neck instead of being carried through the metal of the spindle to the tail.

The saddle, as already mentioned, is not carried on the bed, but on V slides at the front and rear. These slides, being underneath the shears, are protected from chips and dirt. It will also be understood that in gap bed lathes of this construction, when the saddle overhangs the gap, there is no reduction whatever in the bearance. The slides are of the ordinary compound type and are provided with micrometer adjustment.

The lathe, we should say, is exceptionally easy to operate, as all motions, including the reversing gear, are controlled from the saddle in any position on the bed, and, as we have seen above, the clutch for the driving pulley can also be put in or out from any part of the machine. An automatic knock-off is provided for the longitudidal traverse of the saddle, also the usual hand motions, and in addition a safety device to prevent any possible breakage of the feed gears.

The leadscrew is placed directly under the front shear and is provided with a special bearing in the saddle. A reverse motion operated from the saddle is provided for screwcutting giving a return to the saddle of 8 to 1. It will thus be seen that whilst screwcutting the nut need never be disengaged from the screw.

The universal woodgrinding machine shown by the firm is illustrated in Fig. 12. This machine has a vertical sand belt running over accurately balanced large and small drums, which run at high speed; tilting worktables are provided, and the machine is capable of finishing all manner of irregularly-shaped pieces, as well as straight pieces, after rough sawing. The tool, the general construction of which will be understood from the illustration, should save an enormous amount of time and labour in sanding.

Messrs. Webster & Bennett, Ltd., of Atlas Works, Coventry, exhibited three machines, viz., a 36in. duplex boring and turning mill, a 18in. ditto, and a horizontal boring and milling machine, the two former machines being shown in operation.

The 36in. duplex machine we have pleasure in illustrating in Fig. 13. As will be seen, the twin tables make the outstanding feature of this tool, giving, as they do, two independent machines on one base, an arrangement very economical as regards floor space and convenience for the operator. There is also fitted to the tool slide a patent rapid power traverse by means of which much time and hard labour on the part of the operator is saved. The tables of the machine have planed tee grooves, and are driven by spur gears to obviate any lifting tendency, the down thrust being taken on a pressure ring running in oil directly under the chucks. The speed changes are in geometrical progression, the double gearing being put in or out of action without shock while running, by handles at the front, and four table speeds are thus obtained without changing the cone belts. The turrets have, as will be seen, five faces for attaching special tools. They are bored in position, and efficient binders are provided to secure the tool holders. Stops are fitted to set these turrets central when boring, and their slides are balanced and fitted with swivels indicated in degrees for taper boring and turning. The feeds, vertical, angular, and horizontal, are automatic and reversible, the rates of feed being controlled by hand levers conveniently situated.

Safety devices are provided to prevent breakages due to negligence of the operator; the feed trips are actuated by drop worms, and permit of very fine adjustments; the dials are marked 16 per inch to facilitate the setting of the stops and register the progress of the tools over the work; and the rapid power travel of the slides previously mentioned is available in all directions. It is controlled by hand levers, which also disengage the feed works.

The chief features of the 18in. duplex boring and turning mill, which is a machine built on somewhat similar lines to the one described above, are twin tables, and a patent pulley crowning attachment, by means of which pulleys are turned with a rounded face without being turned parallel previously, and without the use of formers, the depth of the crown being adjustable. During the downward movement of the turning tool the attachment operates the horizontal slide, causing the tool to move outwards at a decreasing rate until the centre of the pulley face is reached. The horizontal movement then automatically reverses, and the tool is moved inwards for the remaining half of the pulley face. The down feed is registered on a dial which is used for setting the tool, the dial being indicated to turn pulleys up to 8in. width of face. The depth of crown produced on a pulley of a given width can, of course, be varied by change gear. The crowning mechanism is duplicated, each side being quite independent of the other, and for boring and parallel turning it may be instantly put out of action without disturbing the setting.

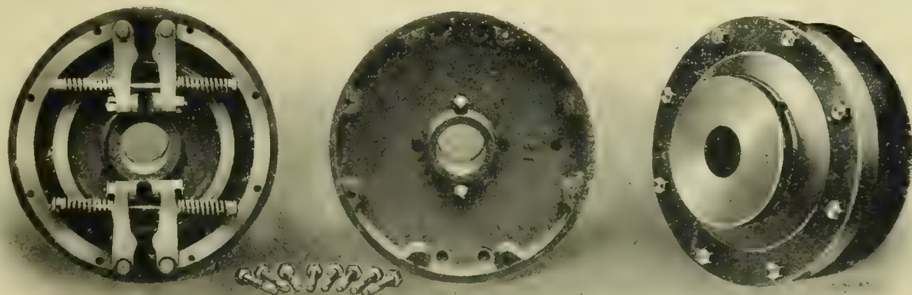


FIG. 14.—THE "SAVER" FRICTION CLUTCH.

A speed box drive is also fitted, which gives an independent drive for each chuck table. This arrangement obviates the

need for an overhead countershaft, and enables any desired speed to be instantly obtained.

The horizontal boring and milling machine shown is likewise a massively-built tool, and this is fitted with a single pulley drive for the spindle, incorporated with which is a reversing motion, making a countershaft quite unnecessary. There is also an automatic feed to the table in all directions, the cross feed being especially used for milling, and the vertical power traverse enabling the heavy table to be raised or lowered without effort, to suit the height of the particular work in hand. This type of machine is designed specially for work which is not too large to be fastened to a movable table, which is adjusted to suit the boring bar. It is also very suitable for jig work and anything that does not require very great height above the table. All the motions permit of rapid handling, and in conjunction with the compound and circular movements of the table form valuable time-saving features.

Messrs. The "Saver" Clutch Company, Ltd., of 30, Spring Gardens, Manchester, showed several examples of their metal-to-metal friction clutches, in sizes from 5 h.p. to 60 h.p. They are, however, made to transmit any power at any speed, and can be made to slip at any particular load. The photo-

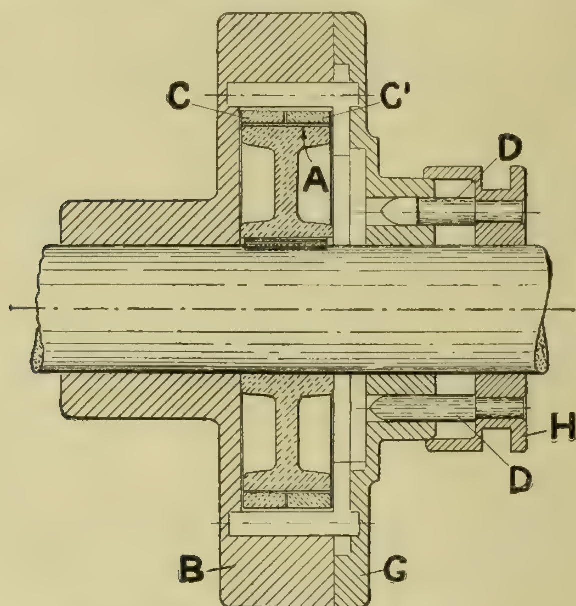


FIG. 15. SECTION OF THE "SAVER" FRICTION CLUTCH.

graphic illustration, Fig. 14 shows a clutch dismantled, and the line drawing shown in Fig. 15, together with the following description, will make their working clear.

As will be seen, the clutch consists of two crucible spring steel rings or bands C and C_1, which are forced into frictional contact with the surface of a drum A by tension springs. The pressure on these springs can be readily adjusted by nuts to enable the bands to slip at any predetermined load. The sliding sleeve H carries two conical-shaped plungers D, which, acting upon the levers, force them apart, gradually releasing the pressure of the bands C and C_1 on the drum A, finally carrying them quite clear of the drum. There is thus no metal-to-metal contact when the clutch is out of gear, and as the clutch runs in oil it is an impossibility for any heating up and consequent binding to take place. It is important to note that as the plungers D are arranged with their points one in advance of the other the action of the clutch is progressive, that is to say, one band engages with the drum in advance of the other, thus causing the speed and power to be taken up gradually. The grip bands engage at diametrically opposite points, one after the other, and make an exact balance in weight and distribution of power. Either the drum A or the casing B may be the prime mover. The whole of these simple parts are enclosed in an oil-tight and dustproof case B, and when the cover G is bolted in place the case is filled with oil through the plug hole. The bands C, it will be observed, grip the crucible total periphery of the drum A, unlike many other clutches which only grip in portions of the circumference.

The characteristic of being able to regulate the clutch so that at any desired load it may slip, is taken advantage of when fitted to many machines which are capable of being overloaded, with a consequent inevitable breakdown, and in this connection we may mention that it has already been applied to machines driven by electric motors for the cleaning of water mains, where an obstruction in the pipe means either a breakdown of the motor or of the cleaning machine itself.

With single-phase and multi-phase motors this clutch is also being largely used, owing to the qualities before described, especially as it starts so smoothly and easily, and yet is positive in its grip when fully in gear. As the clutch gear is immersed in oil, its life is also very much longer than any dry clutch to which dust and grit have access. We understand that several have been running in omnibuses for the last three years, and that the first new band was only supplied a couple of months ago. During all this period the clutch has been running we are told that it has given no trouble whatever.

OIL ENGINES FOR MARINE PROPULSION.

AT the opening meeting of the new session of the Institution of Engineers and Shipbuilders in Scotland, held at Glasgow on the 22nd ult., Mr. E. Hall-Brown, the president, after a reference to the recent celebrations of the centenary of steam navigation on the Clyde, said the supremacy of the steam engine for marine propulsion was now threatened by the advent of a newer motive power. In the year of the "Comet" centenary three sea-going vessels propelled by Diesel oil engines had been completed and dispatched from Great Britain, and there were now built or under construction in the world over 50 vessels of considerable size, all fitted or to be fitted with such engines. So far the older 4-stroke cycle type predominated, but excellent results had been attained with 2-stroke cycle engines. There were thus two lines of present development—the somewhat high-speed engines of the 4-stroke type, usually enclosed and fitted with forced lubrication, and the slow-speed engine of the open type. It was evident that with higher speeds of revolution the dimensions and corresponding first cost of the engines could be reduced—this was an important item. He feared, however, that with ordinary cargo vessels this increase in speed of revolutions, and consequent reduction in first cost, could be attained only at the sacrifice of propeller efficiency. If that was so, lower speeds of revolution might be employed in future, especially in single-screw vessels.

In the case of the oil-engined vessel "Eavestone," it had been found possible to reduce the revolutions considerably, and at the same time obtain a satisfactory increase in speed. This vessel was specially interesting because she afforded direct comparisons with a large fleet of similar vessels driven by ordinary triple-compound steam engines. Compared with the best of these the "Eavestone" showed a considerable commercial gain, in spite of the present high price of oil in Great Britain and on the Continent. Her last voyage showed an average speed loaded of 9·41 knots at sea, with an oil consumption of 3·6 tons per 24 hours. The steam-driven vessels of the same dimensions but of slightly less carrying capacity averaged 8 to $8\frac{1}{4}$ knots loaded, on a consumption of 13 tons of coal per 24 hours. The present price of oil fuel, which was in the neighbourhood of 70s. per ton, was a considerable handicap when a vessel was trading from Great Britain to European ports, but in a voyage which the "Eavestone" had just started—from Hartlepool to Spain, the United States, and home—the bunkers could be filled in America at about 30s. per ton. So long as the present high prices of oil ruled in this country the vessel would take the bulk of her supplies from the United States. From the shipowner's point of view the "Eavestone" showed a satisfactory return on the capital involved, even with oil at its present prices. He wished to add, however, that the margin of profit as compared with steam was not all gain, as the initial cost was higher in the case of the oil engine. From the sea-going engineer's point of view the improvement was marked, as life was much less arduous and the conditions much more pleasant on oil-engined vessels than on those propelled by steam engines. Future developments were, he concluded, dependent entirely on the cost of fuel.

JUNG'S DOUBLE-ACTING COMPOUND ENGINE.

The accompanying illustrations show a design of double-acting compound engine with stage piston, the invention of Mr. Robert Jung, 2, Rehmstrasse, Osnabrück, Germany. Fig. 1 is a horizontal section of the engine taken through the outlet valves. Fig. 2 is a partial lateral view of the engine. Fig. 3 is a section on line 1—1 of Fig. 1. Fig. 4 is a partial section on line 2—2 of Fig. 1; and Fig. 5 is a partial cross-section of the engine on line 3—3 of Fig. 1

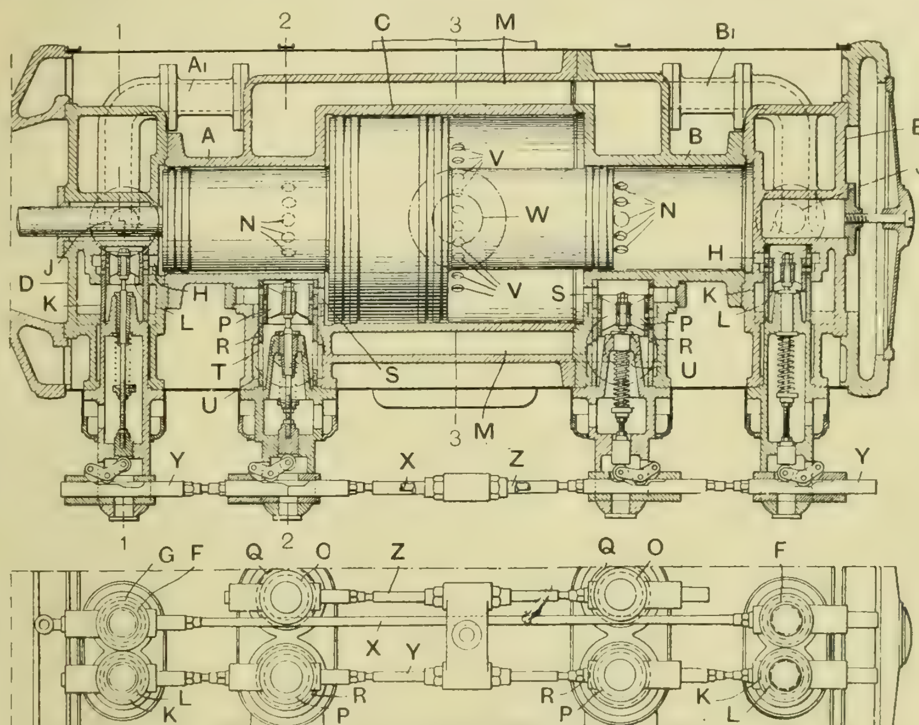
The engine comprises two single-acting high-pressure cylinders A and B, the pistons of which work in opposite directions, and a double-acting low-pressure cylinder C with a double-acting piston working therein. The cylinders are arranged as in a tandem engine, the low-pressure cylinder being directly interposed between both high-pressure cylinders. The pistons are connected so as to form a staged piston in which the high-pressure pistons are the end portions and the low-pressure piston the middle portion. The free ends of the high-pressure cylinders are provided with steam jacketed covers D, E. On these covers, and transverse with respect to the stage piston axis, are mounted the inlet valves of the piston type for the live steam. These piston valves are arranged inside a tube-shaped housing G (Figs. 2 and 3) which, by means of its steam ports, controlled by the piston valves, open into ducts H provided inside the steam jackets, the ducts being tightly separated from the jackets and opening into the high-pressure cylinders. The live steam is conveyed to the engine through connecting branches J, which open into the corresponding steam jackets of the covers. The free end of the housing G is continuously connected with the steam jacket. Into the ducts H are projecting also the tube-shaped housings K of the auxiliary outlet valves L for changing the compression in the high-pressure cylinders (Figs. 2 and 3).

The steam jacket M of the low-pressure cylinder serves as a receiver. The high-pressure cylinders act partially according to the unidirectional flow principle, outlet ports N controlled by the corresponding high-pressure pistons being provided in the peripherical surface of the cylinder, at the ends of the high-pressure cylinders and laterally to the front surfaces of the low-pressure cylinders (Figs. 1 and 4). For directly conveying the steam escaping from these ports to the receiver, the steam jacket extends towards the cover ends of the high-pressure cylinders to such an extent that the ports N are opening direct into the receiver M. This receiver is connected with the auxiliary outlet valves L by means of short ducts A_1, B_1, which pass through the steam jackets of the cylinder ends and are connected with the tube-shaped housings K (Fig. 3).

Between the front walls of the low-pressure cylinder and the front walls of the receiver M are provided the inlet piston valves O and the auxiliary piston valves P of the low-pressure cylinder. These piston valves are disposed in such a manner that the valve housings Q and R are connected with the interior of the low-pressure cylinder by means of corresponding common ducts S. The free end of the housing Q opens into the receiver M, whilst the housing R is connected through an opening T and branches U with the condenser or exhaust piping (Fig. 1). The low-pressure cylinder also partially works in unidirectional flow manner, outlet ports V, controlled by the low-pressure piston, being provided in the middle of the cylinder, these ports opening in an exhaust duct connected with the condenser or exhaust piping (Fig. 5).

The distributing gears are controlled by cam connecting rods, the inlet valves of the high-pressure cylinders being controlled by the connecting rod X, which is under the action of a shaft governor, the auxiliary outlet valves of the high-pressure cylinder and the auxiliary valves of the low-pressure cylinder being controlled by means of a connecting rod Y and the inlet valves of the low-pressure cylinder being controlled by means of a rod Z connected with the connecting rod Y.

The working of the engine is as follows: In the left-hand dead point position of the stage piston the live steam enters through the tube J into the steam jacket of the cover D (Fig. 3) and through the slide valve F and the duct H into the high-pressure cylinder A. Just before reaching the right-hand dead point of the staged piston, the high-pressure piston uncovers the outlet ports N, so that the greatest part of the steam flows in unidirectional flow into the receiver M. When the staged piston moves back the remaining steam of cylinder A is expelled through the duct H, the valve L and the tube A_1 and forced into the receiver M until the compression controlled by the valve L begins in this cylinder. This steam, expelled in opposed directional flow is strongly heated when passing the steam jacket of the cover D. At the end of the piston stroke the unidirectional flow exhaust steam of the high-pressure cylinder B, which enters at the end of the receiver through the ports N, is joining the foregoing steam. This exhaust steam strikes the back end of the low-pressure cylinder, then the peripherical surface of this cylinder, and after having struck the front end it flows, together with the exhaust steam of the second high-pressure cylinder, through the valve O and the duct S to the low-pressure cylinder (Fig. 4). At the stroke end most of the exhaust steam flows through the exhaust ports V, uncovered by the low-pressure piston, into the outlet piping W and into the condenser. The steam which did not flow through the outlet ports V is directed through the duct S and through the outlet valve P, which serves as regulating means for the compression in the low-pressure cylinder into the piping U and from this piping into the condenser.



Figs. 1 and 2. Jung's Double-acting Compound Engine.

The live steam entering the high-pressure cylinder B through the piping J, the valve F, and the duct H, flows through the engine in the same manner as the live steam entering the high-pressure cylinder A, but in an opposite direction, owing to the greater part of the steam, directed in unidirectional flow manner, entering directly into the receiver M through the ports N, and, after having flowed around the low-pressure cylinder and united with the alternate current exhaust steam of the high-pressure cylinder A, entering at the opposite side of the low-pressure cylinder through the inlet valve O. The exhaust steam of the high-pressure cylinder B, flowing in opposite directional flow manner, enters the receiver M through the duct B_1, during the back stroke of the piston. During the following expansion stroke of the piston it flows, together with the equi current stream of the high-pressure cylinder A through the inlet valve O into the low-pressure

cylinder and leaves the engines through the ports V and the piping W.

The condensation of the live steam, whilst entering in the high-pressure cylinders, is very small, notwithstanding the possibility of adjusting the compression, because, when directing the larger part of the exhaust steam in unidirectional flow, the cooling surfaces remain relatively hot. The condensation in the low-pressure cylinder is also very small, because this cylinder is heated all around by means of moving steam, the steam from the outlet ports controlled by the high-pressure pistons being made to flow in opposite directional flow along-

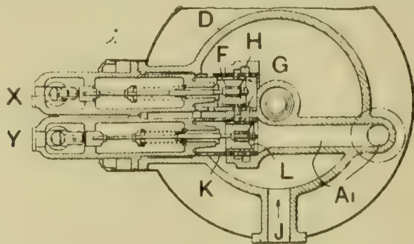


FIG. 3.

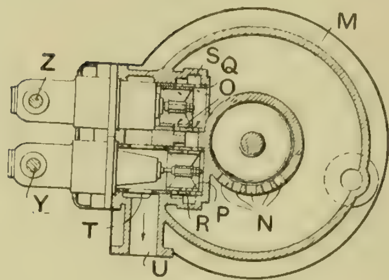


FIG. 4.

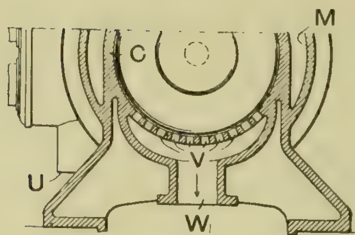


FIG. 5.

side the front ends and the peripherical surface of the low-pressure cylinder and entering this cylinder at the other cylinder end. The losses of heat whilst the steam is passing from the high-pressure cylinders into the low-pressure cylinder are very low, because the larger part of the exhaust steam of the high-pressure cylinder flowing in unidirectional flow manner passes directly into the receiver M, whilst the smaller part, viz., the cool opposite directional flow exhaust steam of the high-pressure cylinders, owing to the end steam jackets, are brought at such a high temperature that its temperature reaches at least that of the exhaust steam flowing in equi current manner.

Telegraph and Trolley Wires.—A deputation representing the Municipal Tramways Association and the Tramways and Light Railways Association waited upon the Postmaster-General at the General Post Office, on the 25th ult., in reference to the guard wires over overhead electric trolley wires where telegraph and telephone wires cross. The deputation included tramway managers and others interested in tramway undertakings from all parts of the country. It was pointed out that they wished to secure the removal of telegraph and telephone wires crossing overhead trolley wires, and suggested that the telegraph and telephone wires should be placed underground or insulated. At present tramway authorities are compelled to have guard wires over their trolley wires at points where the telegraph and telephone wires cross the overhead tramway wires. The suggestion, therefore, is that the Post Office Authorities should protect their own wires instead of the tramways authorities being responsible for their protection. The Postmaster-General promised that consideration would be given to the request of the deputation.

AUTOGENOUS WELDING OF ALUMINIUM-COPPER AND ITS ALLOYS.*

BY DR. F. CARNEVALI.

(Concluded from page 531.)

Brass.—A third series of experiments was conducted, by the same methods as the two series already described, with the types of brass fusible at high temperatures, here designated respectively as M and N. Their composition is as follows :—

	M.	N.
	Per cent.	Per cent.
Copper	60·2	55·18
Zinc	40·08	41·50
Manganese	—	3·2

The first mentioned was cast in rods, measuring 30 millimetres ($1\frac{1}{5}$in.) in diameter, in dry earth moulds; the other was wire-drawn into rods, 25 millimetres (1in.) in diameter. The welding material consisted of very thin rods, in each case of exactly the same composition as the original alloy. The phenomenon of the unwelcome vesicles, set up in large numbers within the welding zone, despite all the preventive precautions that could be taken, was intensified in the case of these alloys by the extreme facility with which the zinc contained in the metal oxidises. In the accompanying Table IV. are set forth the results obtained from shock tests and from chemical analysis of the various samples.

TABLE IV.—*Shock Tests with the Charpy Apparatus.**

No. of Sample.	Thermal Treatment.	Indicated Angle.	Breaking Test. Kgs. Mm.	Mean Chemical Analysis. Of the Metal. Per cent.	Mean Chemical Analysis. Of the Weld-Zone. Per cent.	Remarks.
M1	Reheated	128°	4·646	Cu= 60·2 Zn= 40·08	—	Not welded.
M2	Cooled in air after welding.	141°	2·112	—	Cu= 69·3	Welded; finely granular fracture; numerous vacuoles.
M3	Reheated after welding.	138°	2·646	—	—	Do. do.
N4	Reheated	128°	4·646	Cu= 55·18 Mn= 3·2	—	Not welded.
N5	Reheated after welding.	140°	2·286	—	Cu= 68·75 Mn= 1·2	Welded; medium grained fracture; numerous vacuoles.

* See Table II.

Microscopic examination, confirming the results here tabulated, leads to the same conclusions as those postulated in regard to the bronzes. In order, therefore, to avoid needless repetition, I will content myself with referring the reader to what has already been said on that point. We may note, however, in these alloys a diminution in the capacity, when heated, of absorbing the products of combustion of the welding flame; coincidently with this diminution, the liability of the welded parts to fracture along the margins of the chamfer decreases. In confirmation of the results yielded by chemical analysis, Fig. 6 (usual enlargement, simple etching), reproduces the structure of the passage-zone between the original metal and the fused welding material (sample 2, Table IV.); while in the former, towards the top of the figure, we observe the typical structure of the alloy, consisting of mixed crystals of the "solid solutions" α and β; in the latter we note the presence of a single constituent, the "solid solution" α, resulting from the considerable decrease in the percentage of zinc revealed by chemical analysis. In this portion of the metal, numerous inclusions of oxide of zinc, formed in the course of the welding process, are to be seen.

CONCLUSIONS.

The results obtained and the observations recorded in this triple series of investigations concerning the oxy-acetylene autogenous welding of copper and its chief alloys demonstrate :—

* Abstract of paper read before the Institute of Metals, September, 1912.

(1) That rapid heating and sudden fusion of the metal subjected to welding profoundly modify its physical and mechanical properties, developing within it internal strains and structural alterations which are of detrimental effect.

(2) That the structural modifications which take place in the process of welding, apart from the alterations in composition of the metal, may be classified under two principal headings: (i.) coarse crystallisation of a single-constituent metal, and (ii.) minutely heterogeneous structure of an alloy consisting of two or more elements. We must also take into account the discontinuity of structure attaching to metals in which there are oxide inclusions or vacuoles.

(3) That the deficiency in mechanical properties, most conspicuous in all that regards the tenacity and elasticity of a metal, is expressed in the case of copper by an average reduction of 50 per cent. in the capacity to resist fracture, and an increase of about 30 per cent. in brittleness, while the percentage ductility is reduced to about a tenth of the original. In the case of bronzes and brasses, the deficiency in mechanical properties is not susceptible of rigorous mensuration, but it is greatly intensified and proportionately detrimental as the number and variety of the constituents of the alloy subjected to welding are increased.

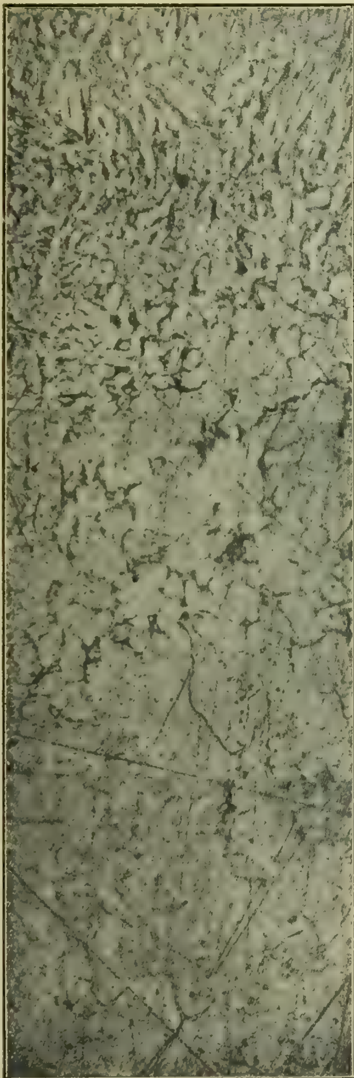


FIG. 6.

(4) That, while mechanical treatment, such as hammering along the zone of welding, has practically no useful effect on the properties of the welded metal, thermal treatment, such as reheating, prolonged for a suitable interval at a fixed temperature, exerts an undoubted ameliorative influence, since in the first place it relieves the latent internal strain set up by the sudden temperature-changes involved in the process of welding, and in the second place it restores homogeneity to the structure of the metal itself. Consequently, and more particularly in the case of alloys made up of several constituents, the conditions of cooling of the welded metal are of special importance, the slower the cooling the greater being the ameliorative effect.

(5) That considerable variations—diverse according to the manner in which the process of welding is applied—occur in the composition of bronzes and brasses; these variations are the more extensive the greater the number of constituents of which the alloy is made up, and also in proportion to the affinity of these constituents for oxygen and to the volatility of the oxides formed therefrom. Thus, for example, in the bronzes of type B (Table III.), in the welded zone, there is an average diminution of 19·0 per cent. in the proportion of tin; while the loss of zinc, a more easily oxidised metal than tin, amounts to 22·3 per cent. (the original proportion present being smaller than that of tin). In brasses, wherein the percentage of zinc is much higher, its decrease in the welded zone amounts to 28·7 per cent. We must also bear in mind that the oxides thus formed have a tendency to diffuse easily into the metal, modifying profoundly its properties. In pure copper subjected to the welding process changes in chemical composition cannot be traced, as the metal is made up of a single constituent; and it is only affected deeply by oxidation when the necessary precautions have been omitted in the process of welding, the suboxide then formed diffusing with great facility into the copper.

(6) That taking into account the results obtained and the conclusions here postulated, we may assert that the oxy-acetylene autogenous welding of copper and its principal alloys has a practical application, limited to those parts of machinery which are not of large dimensions and are not subjected to severe mechanical stresses.

Aluminium.—The experiments on this group were carried out with two types of metal, one designated by the letter S (see Tables V. and VI.), consisting of pure aluminium containing 99 per cent. of the metal,* in the form of rods of two different diameters (30 and 12 millimetres respectively) and of flat bars, 6 millimetres thick; the other, designated by the letter T (see Table V.), in the form of rods, 15 millimetres in diameter, consisting of aluminium alloyed with 3 per cent. of copper (a type of alloy in common use industrially). The welding material consisted of thin rods of metal of identical composition with S and T respectively. The experiments were conducted under precisely the same conditions as those of the previous series, especial care being taken to avoid oxidation, to which the metal is so easily liable during the process of welding. For this purpose appropriate deoxidising powders were used. In the accompanying Tables V. and VI. the results obtained are set forth in detail.

Micrographic study of the several samples, pursued by the same method as that followed in the foregoing series of investigations, enabled one to identify without difficulty the welding zone by its coarsely granular structure. This structure is a consequence of the high temperature attained by the metal in fusion, and is illustrated in Fig. 7 (enlarged 80 diameters; etching by an aqueous 10 per cent. solution of caustic potash). This represents the weld-zone of sample S7 (see Table V.); the thin, dark filaments or threads which it reveals are the margins of the big crystals, while within the crystals themselves are seen small, and exceptionally numerous, dark, rounded inclusions—less abundant in the other samples—formed by the oxide which has remained imprisoned in the metal. In this case oxidation was especially active during the process of fusion. This structure, which repeats itself in the various samples of type S, undergoes modifications varying according to the different treatment to which the metal is subjected. Hammering, for instance, tends to approximate the structure of the weld-zone to the original texture of the metal; while reheating tends to make the texture of the entire weld-zone homogeneous, eliminating the internal strains set up within the metal as a consequence of rapid fusion and similarly rapid cooling.

TABLE VI.—*Shock Tests with the Charpy Apparatus.* (*See* Table II.)

No. of Sample.	Initial Dimensions of Sample.	Thermal and Mechanical Treatment.	Indicated Angle.	Breaking Test. Kgs. Mm.	Brinell Hardness (average), 500 Kgs.	Remarks.
S1	Rods, 20 mm. in diameter.	—	117°	7·181	—	Not welded.
S2	Do.	Reheated.	110	8·936	27·2	Not welded.
S3	Do.	Cooled in air after welding.	141°	2·112	—	Welded; medium-grained fracture; small vacuoles.
S4	Do.	Reheated after welding.	119	6·698	25·9 in the weld.	Same as above, but no vacuoles.
S5	Do.	Hammered and reheated after welding.	128°	4·646	27·2	Do. Do.

In contradistinction to the phenomena observed in the case of copper, the oxy-acetylene autogenous welding of pure aluminium results in an intimate union between the latter and the welding material, the two substances forming an inseparable *corpus*, as is shown by bending and torsional tests (in the cold). These observations are confirmed also by the contraction which takes place in the fracture-zone of the welded metal subjected to the torsional test, and by the high coefficient of quality recorded

* Kindly supplied by the British Aluminium Company, Ltd., London.

in the case of the welded samples (see Table V.). We must bear in mind, however, that the values obtained as a result of tests carried out on samples of considerable dimensions (see Table V., 3 and 4) are somewhat low, on account of the difficulty of obtaining a perfect weld in the innermost portions of the chamfer. The results yielded by the tests carried out with the second type of



FIG. 7.

aluminium (type T), alloyed with 3 per cent. of copper, tend to prove by the low values obtained that the addition of copper to the aluminium facilitates oxidation of the metal during the process of welding, the complete success of which cannot, therefore, be guaranteed.

CONCLUSIONS.

The data accumulated and the observations made in the course of this series of experiments with the oxy-acetylene autogenous welding of aluminium, show :—

(1) That sudden heating and rapid fusion of the metal subjected to the welding process alter its physical and mechanical properties in a manner analogous to that observed in the case of copper, though in less degree. They set up within the metal latent internal strains, and modify its structure detrimentally.

(2) That the structural modifications, induced by excessively rapid heating during the process of welding, take the form of coarse crystallisation of the metal.

(3) That, so long as all the necessary precautions are observed in the process of welding, the changes in the mechanical properties of pure aluminium, such as breaking strain, ductility, hardness of the weld-zone, are not very profound, although a notable increase in brittleness is observable, as is shown by the results of shock tests. The presence of copper, however, modifies profoundly in a detrimental sense the mechanical properties of aluminium.

(4) That, in consequence of the feasibility of achieving with pure aluminium a perfect and homogeneous weld of the metal, both mechanical (hammering) and thermal (reheating to 450° to 500° C.) treatment is extremely efficacious, in that it sets up greater homogeneity in the weld-zone, and eliminates the effect of the excessively rapid heating undergone in process of welding, ameliorating consequently the quality of the metal.

(5) That whenever aluminium contains small quantities of other elements easily oxidisable at high temperatures (as, for example, copper), the oxidation of the metal in fusion is facilitated, also the inclusion within it of granules of oxide detrimental to the mechanical properties of the weld-zone.

(6) That, taking into account the results obtained, as also the foregoing conclusions, we may assert that the oxy-acetylene autogenous welding of aluminium, when carried out with the necessary precautions, is capable of extensive application in practice, especially for the autogenous welding of small machine parts.

TABLE V.

No. of Sample.*	Mean Dimensions of Sample in Millimetres.	Thermal and Mechanical Treatment.	Average Ultimate Stress. Kgs. per Square Mm.	Mean Elongation up to Breaking Point per cent.	Contraction.	Cold Bending Tests on the Weld-Zone.	Remarks.
S1	Diameter = 16; useful length = 100	—	12·7	16	8·3	—	Not welded.
S2	Do.	Reheated	11·5	18·5	7·8	—	Do.
S3	Do.	Cooled in air after welding	5·4	4·3	14·5	—	Welded; rupture at the weld; fibrous fracture with vacuoles.
S4	Do.	Reheated after welding....	8·6	5·1	13·2	—	Same as above, but fracture oxidised. Vacuoles not mentioned.
S5	Diameter = 8; useful length = 80.	—	16·8	10·0	4·0	—	Not welded.
S6	Do.	Reheated	14·2	16·1	3·2	180°	Not welded.
S7	Do.	Cooled in air after welding	7·6	4·0	7·0	180°	Welded; rupture at the weld; fibrous fracture.
S8	Do.	Reheated after welding....	7·0	8·8	6·5	—	Do. do.
S9	Do.	Hammered after welding ..	8·2	5·1	6·3	180°	Do. do.
S10	Do.	Hammered and reheated after welding.	8·6	15·6	5·5	—	Do. do.
S11	20 5. Useful length = 100.	—	12·0	7·2	16·8×1·9	—	Not welded.
S12	Do.	Reheated	11·4	14·2	16·9×3·5	180°	Do.
S13	Do.	Reheated after welding....	7·7	9·2	18·2×3·2	—	Welded; rupture at the weld; fibrous fracture.
S14	Do.	Hammered and reheated after welding.	9·2	17·5	16·5×2·5	180°	Do. do.
T15	Diameter 10; useful length 100	—	18·5	13·5	6·5	—	Not welded.
T16	Do.	Reheated	15·8	18·1	7·0	—	Do.
T17	Do.	Cooled in air after welding	5·0	0·9	10·0	—	Welded; ruptured at the weld; coarsely granular oxidised fracture; vacuoles.
T18	Do.	Hammered and reheated after welding.	7·2	2·1	9·7	—	Welded; ruptured at the weld; medium-grained fracture; vacuoles.

* Two samples, prepared and treated in identical fashion, correspond to each number.

RELIABILITY IN HIGH-LIFT CENTRIFUGAL PUMPS.*

BY W. E. W. MILLINGTON.

During the last few years many papers dealing with centrifugal pumps, particularly with those of the high-lift type, have been read before various institutions. The majority of these papers have described various pumps and given accounts of their performances with the object of showing the best efficiencies which can be obtained with a pump possessing so

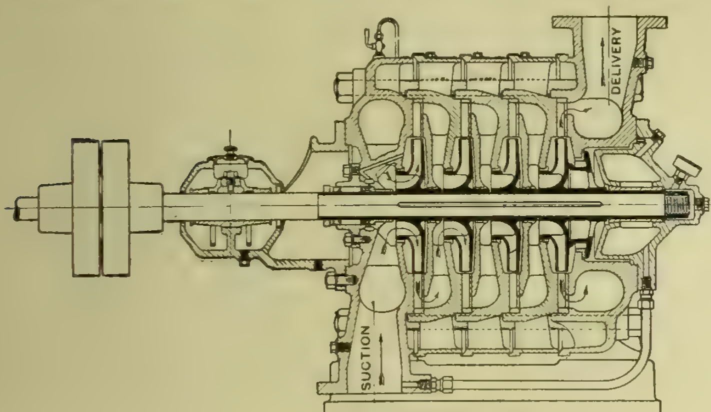


Fig. 1.

many peculiar characteristics and so many advantages as a high-lift centrifugal. Although it is desirable to aim at high efficiency, this is useless unless it be associated with reliability. It is the author's contention that in designing a pump of this description, reliability should be the primary and that efficiency and price should be secondary considerations. Reliability is obtained partly by paying due regard to many points in design and partly by installing and running the pumps under proper conditions.

It is impossible within the limits of a single paper such as this to deal with the whole subject of high-lift centrifugal pumps, hence the author's excuse for bringing before the notice of this Association a paper which, while omitting much of theoretical and practical interest, deals with only a few practical points which aim at securing reliability in the design, installation, and running of this type of pump and its accessories.

At the present time centrifugal pumps are used with advantage for almost every conceivable duty. There are pumps dealing with large quantities, such as 60,000 galls. per minute against low heads of 10ft., and others dealing with quantities of as much as 2,000 galls. per minute against heads of 2,000ft. The chief occasion when it is not advisable to install centrifugal pumps is when only a small quantity

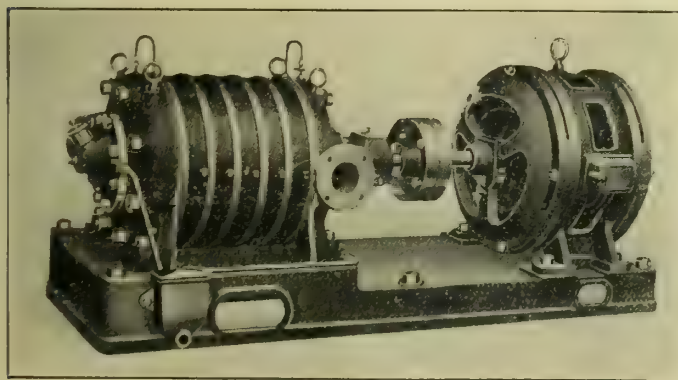


Fig. 2.

of water is required to be raised against a very high lift. In such a case as this it is impossible at the present time to build a pump of this type having such an efficiency as would warrant its being installed in preference to a reciprocating pump. Judging from the title of this paper, it might be thought that there is some hard and fast line dividing low lifts and high lifts. This is not so. This distinction applies rather to the design of the pumps than to anything else, for it sometimes happens that the high-lift type of pump is used for quite low lifts.

A pump which is or can be easily made into one in which the full head is impressed upon the water in a number of stages arranged in series and so as to form a self-contained machine is usually said to be of the high-lift type. This type of pump is sometimes called a turbine pump, and is also known by various trade names, but in principle they are all the same, and, to prevent confusion, the author prefers that all pumps in which energy is given to a liquid as it flows in a more or less radial direction through a rotating impeller should be called centrifugal pumps.

Before proceeding with the main points of the paper, it may be well just to glance at the general working of a high-lift centrifugal pump, and with this object in view the Figs. 1 to 4 have been prepared. Fig. 1 shows a section of a 4-stage pump of the same type as the 6-stage pump illustrated in Fig. 2; Fig. 3 shows the rotating impellers in position on the shaft, and Fig. 4 shows a middle body of the pump complete with its impeller and ring of guide passages. Water enters the pump through the suction branch shown in Fig. 1 and follows the direction indicated by the arrows. The water, on leaving the periphery of the first impeller, enters the guide passages, which are clearly shown in Fig. 4, and is led round to the entrance of the second impeller, having then had approximately one-fourth of the whole head impressed upon it. This head has been obtained partly, directly owing to the action of centrifugal force as the water passes through the impeller, and partly, indirectly by the conversion of the velocity with which the water leaves the impeller into pressure energy as it traverses the guide pas-

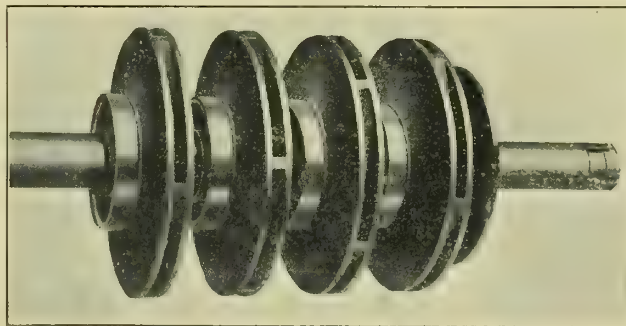


Fig. 3.

sages. The same operation takes place in the other stages of the pump, and finally the water is discharged through the delivery branch under the full head.

In order to make this preliminary description complete, Fig. 5 is given, showing the characteristic curves taken from a pump of this description running under the most usual condition, namely, at a constant speed. All the observations were made with the pump running at a speed of 1,400 revs. per minute. The general shape of these curves holds good for practically all types of centrifugal pumps.

To ensure reliability, it is essential that the various parts of the pump should be constructed of materials suitable for the conditions under which they have to work. In cases where the water contains any matter in suspension the impellers and guide passages should be made of phosphor-bronze, and in cases where the pump has to stand idle for some time, as, for instance, when installed as a fire pump, it is desirable to make in gun-metal those parts which have only a running clearance between them.

It almost goes without saying that reliability cannot be obtained unless proper attention be paid to the machining of all parts of the pump and all rotating parts be correctly balanced to prevent vibration when running. Many of the failures of the early high-lift centrifugal pumps can be traced to faulty machining. Perhaps one of the greatest difficulties with which manufacturers have had to contend in order to secure reliability is the balancing of the axial thrust produced by the impellers when the pump is running. A glance at Fig. 6 will show how this thrust arises.

For the sake of example it is assumed that, when running, the pressures at the entrance and periphery of one impeller and at the entrance to the next impeller are represented by 10, 20, and 30 respectively. There will be a leakage from the

* Paper read before the Manchester Association of Engineers, October 26th, 1912.

periphery of the impeller through the space A into the space under pressure 10, and from the space under pressure 30 through the space B to the periphery. The mean pressure, therefore, in the space A will be between 10 and 20, say 15, and in the space B will be between 20 and 30, say 25. It will be clear, therefore, that when running there will be an excess pressure acting on this impeller in the direction of the

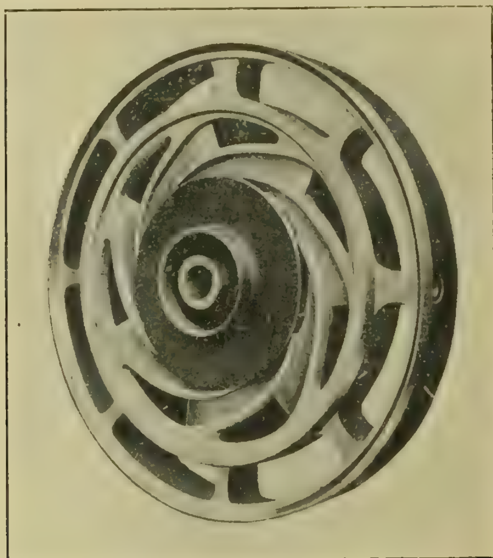


FIG. 4.

arrow X. It is the satisfactory balancing of the sum of these pressures acting on all the impellers which has been the aim of pump designers for several years. Figs. 7, 8, and 9 show three methods which have been employed to attain this.

In Fig. 7 the impellers are placed back to back in pairs, with the idea that the load acting on one impeller in one direction should balance the load acting in the other direction on the other impeller. This method possesses the obvious disadvantage that the pump can only be built up with an even number of impellers. In the method shown in Fig. 8 the sides of the impeller are made of different diameters giving a smaller area on the side upon which the larger pressure is acting. As may be imagined, it is extremely difficult to calculate what the difference in diameter should be in order to balance the impeller. In Fig. 9 the additional neck ring R is provided and holes H put through the side of the impeller, so as to make the conditions of pressure the same in both spaces A and B.

On paper in any one of these methods the end thrust is eliminated, but even then it is necessary to employ some form of thrust bearing in order to keep the impellers running in their correct axial positions. As will be readily seen, slight

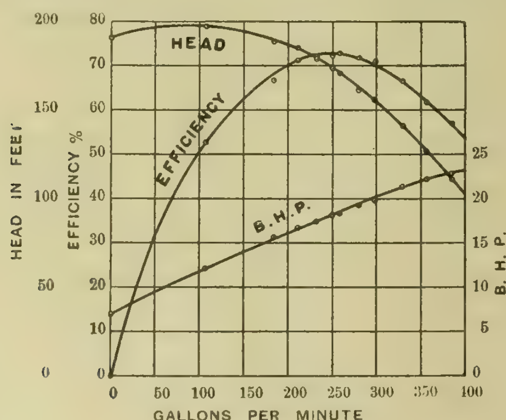


FIG. 5.

differences in the clearances between the rotating and stationary parts at the points where these clearances are small to prevent leakage, and uneven wear at these points, also differences in the surfaces of the outside of the impellers will cause a difference in pressure on the two sides of the impellers and thus produce an axial thrust in one direction or another. In practice, with pumps designed on these lines, it is always necessary to employ a substantial thrust bearing to take this unbalanced axial load.

In another design no attempt is made to balance each impeller, but the total load acting on all the impellers is taken up hydraulically upon some form of piston such as is illustrated in Fig. 10. Here water under pressure passes from the periphery of the last impeller and leaks past the piston B into the chamber C. The outlet from this chamber is controlled by the valve D, and by adjusting this valve any desired pressure can be obtained in the chamber C. After passing the valve D the balancing water is carried away to a drain by means of the pipe F.

In Fig. 6 it was seen that the thrust on the impellers acts in a direction towards the suction end. The piston B is,

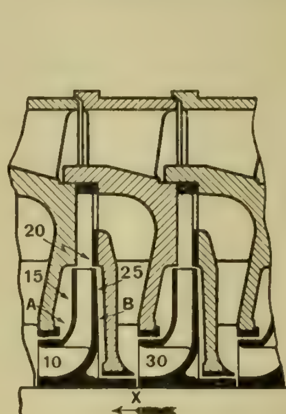


FIG. 6.

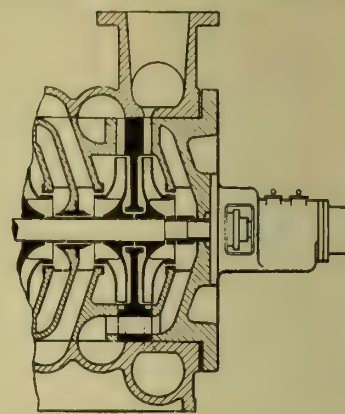


FIG. 7.

however, made of such a diameter that were there no pressure in the chamber C the resulting axial thrust would be in the opposite direction, *i.e.*, towards the delivery end of the pump, due to the decrease in area on the delivery end side of the last impeller. It is therefore possible to balance this axial thrust by establishing a certain pressure in the chamber C. The valve D is adjusted until the pressure is such that the shaft and impellers float axially, and these are then secured in place by means of the thrust bearing E.

This bearing must be of substantial dimensions, as any alteration in the head on the pump or any wear on the periphery of the piston B brings a considerable load on it until the valve D is readjusted. As this method is dependent upon an adjustment by hand of the valve D, it can hardly be said to be really satisfactory or reliable. As a matter of fact, so much trouble has been caused by the use of thrust bearings on high-speed centrifugal pumps that designers have been forced to consider some means of balancing the axial thrust hydraulically and automatically in order to dispense with this form of bearing altogether.

Fig. 11 shows one method in which there is no thrust bearing, and which is an improvement upon that shown in Fig. 10 in so far that the outlet from the balancing chamber C is controlled automatically by the valve D, which moves endwise with the shaft and impellers. If the pressure in the chamber C becomes too high, the shaft, being free endwise,

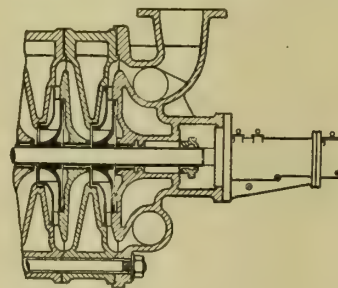


FIG. 8.

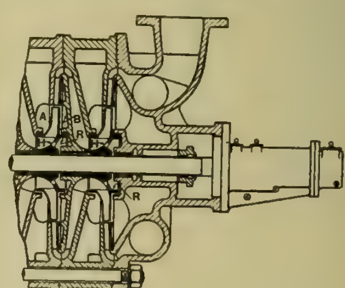


FIG. 9.

will move from right to left, open the valve more, and so relieve the pressure in the chamber. On the other hand, if the pressure in the chamber C be too low the shaft will move from left to right and so increase the pressure in the chamber C. In this way an automatic balancing is effected, and when running the impellers are hydraulically set axially in some position depending upon the head on the pump. In this

design, as wear takes place on the balancing piston, more water will leak past it, and, consequently, to effect a balance the valve D will have to be more open. This throws the impellers more out of their central position, and at the same time the pump efficiency is lowered owing to the increased amount of water passing the balancing valve and away, either to a drain or into the suction pipe of the pump.

Fig. 12 illustrates a design in which the balancing piston is dispensed with, a disc being employed to carry the load necessary to balance the axial thrust of the impellers which is acting in a direction towards the suction end. In this arrangement water leaks from the periphery of the last impeller past the sleeve A, running with a small clearance in the part B of the body of the pump. This balancing water then passes into the small chamber C, one wall of which is formed by the disc D, which is fixed to the pump shaft and revolves with it. The outer edge of this disc forms a valve controlling the outlet of the water from the chamber C. The water, after passing the disc valve, is led away to a drain. It will be easily seen that an axial movement of the shaft and the disc controls the pressure of the water in the chamber C, and therefore when running the disc will take up such a position that the water in the chamber C exerts such a pressure on the inner side of the disc as will balance the thrust on the impellers.

This method has the advantage over that shown in Fig. 11 that there is no large balancing piston to wear. The valve

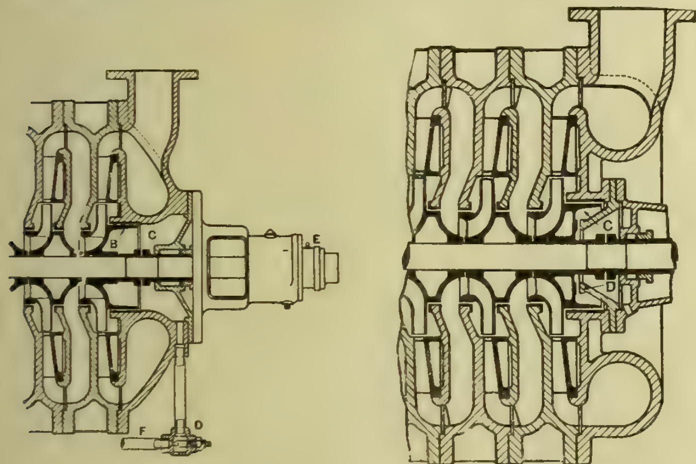


FIG. 10. FIG. 11.

face of the disc is always running clear of the body, and as a result there is not much wear takes place on this; but a further great advantage is that even should wear take place the valve will only remain open by the same amount as at first, the result being that the shaft with its impellers will run a little out of the correct position. No increase of balance water will therefore take place, owing to wear taking place on the disc. If, however, wear takes place on the sleeve A more water will pass through this clearance, since the difference of pressures at the two ends will remain the same. The result is that the disc valve will have to open a little more to allow this excess of water to pass without increasing the pressure in the chamber C. Wear on the sleeve A therefore means that more balance water will be required than when the pump was new.

Fig. 13 shows a method of balancing in which the balancing load is again carried by a disc A, the chamber C forming the balancing pressure chamber. It will be noticed that in this case both the inlet to and the outlet from the chamber C are controlled by means of valve faces on the disc A. A double control is thus obtained, for as the valve B opens owing to an axial movement of the shaft the valve D closes. In this case wear on the valve faces is not automatically taken up as in the case of the design shown in Fig. 12, since, whatever may be the movement of the disc axially due to wear taking place on one or both of the valve faces, the total clearance between both valves and their respective seatings will be increased, and as the drop in pressure between the points E and F remains the same, more balance water will be required. The importance of keeping this total clearance small will be seen when it is stated that a single disc valve such as shown in Fig. 12 is only open two or three-thousandths of an inch when running correctly.

Fig. 14 shows an arrangement of balancing which dispenses with the disc, and which is independent of any wear on any running parts of the pump. In this case a valve A, which is carried from the shaft by means of arms, is so constructed that it fits into a ring cast on the delivery end side of the last impeller. This ring is of such diameter that were there no pressure on the area within the ring there would be a resulting

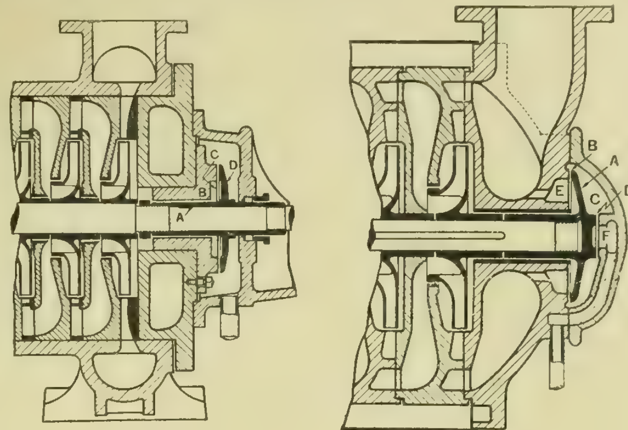


FIG. 12. FIG. 13.

axial thrust on the impellers in a direction towards the delivery end. The load necessary to balance the thrust on the impellers is taken on the back of the last impeller itself, as this forms one wall of the balancing chamber C. The water required for balancing passes from the periphery of the last impeller into the chamber C by way of the valve A. The outlet from the chamber C is controlled by a fixed and definite orifice D. After passing this orifice the water is led away to a drain. In this arrangement any slight wear which takes place on the valve face is automatically taken up by a slight axial movement of the shaft, and no extra balance water is required, as the outlet is controlled by an orifice independent of any running parts of the pump. The only objection which, to the author's knowledge, has been urged against this method is that the orifice D is liable to get stopped up. In practice it is found that this is not the case, and, in fact, it is hardly to be expected when it is realised that the water which passes through this orifice has already passed through a clearance of about ·02in. at the periphery of the last impeller and a clearance of about ·002in. between the valve face and its seating.

Fig. 15 is a photograph taken of a pump fitted with the balancing arrangement shown in Fig. 14. This photograph was taken with a 10-minute exposure while the pump was running at 1,450 revs. per minute. The lower 10in. dial gauge is reading the pressure in the balancing chamber, and the upper one is reading the delivery head on the pump, which is almost entirely friction head due to throttling at the delivery valve. A slight vibration is noticeable on the upper gauge, due to its being connected on the valve itself, but it will be seen that the lower gauge is quite steady. The thin line on the left-hand side and on the horizontal centre line is the balancing water being discharged from the balancing chamber.

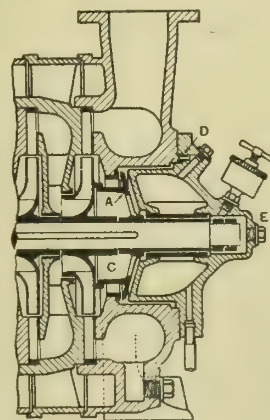


FIG. 14.

The curves shown in Fig. 16 will be of interest, as they show the total head on the pump and also the corresponding pressure in the balance chamber. These readings were taken from the pump shown in Figs. 14 and 15 while running at a constant speed of 1,450 revs. per minute, and the output regulated by means of the delivery valve. Curve C shows the actual amount of water required for balancing expressed as a percentage of the total amount delivered by the pump. Under these conditions of running this particular pump gave a maximum efficiency of 280 galls. per minute, and the balancing water required at this point was only 0·4 per cent. As a further experiment on this pump, the amount by which the balance valve was open was actually measured by the

following means: A small hole was drilled in the valve face and this hole was filled with a soft white metal plug which was allowed to stand a little proud of the valve face. The valve was then replaced in the pump, care being taken to keep it off the seating, and the pump run up to speed with the delivery valve closed. This valve was then opened out until the pump was discharging 250 galls. per minute. The pump was then shut down and the valve taken out. The white metal plug had been worn down, but upon being accurately measured it was found to be ·002in. proud of the valve face, thus showing that under these conditions of running the valve was open by this amount. From this reading and from the curves B and C the curve D has been calculated, showing that the variation in the opening of the valve over the full working range of the pump was only ·0003in. It is difficult to realise that this small amount of axial movement is all that is required to keep the pump perfectly in balance as far as the axial thrust is concerned.

In these various pumps in which the axial thrust is balanced automatically by an endwise movement of the shaft, it is necessary to arrange that they should be coupled to the driving motors by means of a coupling which allows a certain

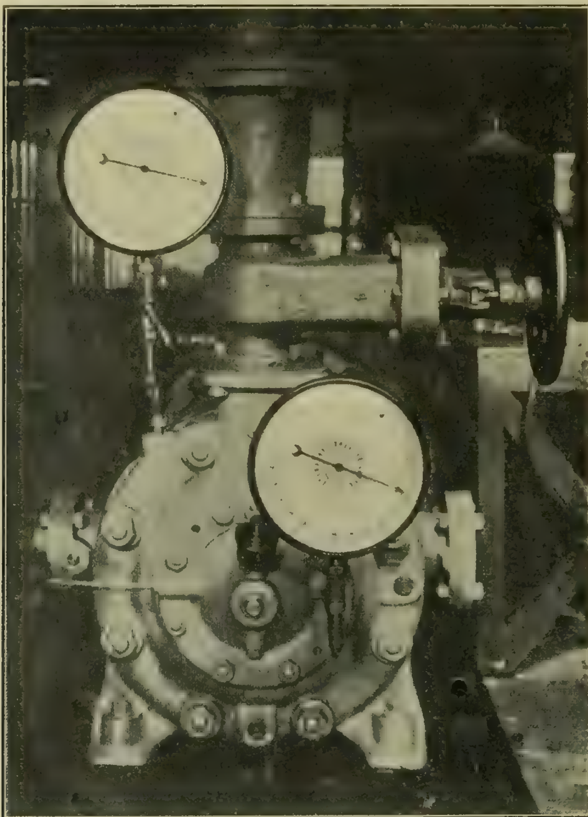


Fig. 15.

amount of axial flexibility. Failing this, it must be possible for the rotor of the motor to move endwise.

The preceding remarks all apply to some of the different methods which have been or are used for balancing the end thrust on the impellers. While this is perhaps the most important difficulty to be overcome to obtain reliability, there are, nevertheless, several other points which deserve careful attention. It is necessary to have some parts of the rotating elements running with a small clearance between them and the stationary parts in order to prevent leakage of high-pressure water into a low-pressure space, and it is clearly an advantage to have these as few in number as possible, and also as small as possible in diameter. Especially is this so in the case of pumps dealing with water containing grit. In the design shown in Fig. 9 it will be noticed that each impeller has three rings running with small clearances. Two of these rings are of large diameter, and the third is only slightly larger in diameter than the shaft, while in the designs shown in Figs. 12, 13, and 14, each impeller has, with advantage, only one large and one small diameter ring. Pumps should be provided with renewable rings at all these points where wear is at all likely to take place.

Stuffing boxes, especially those under pressure, are to be avoided as much as possible. Not only do they mean that more frictional work has to be overcome, but they are often a source of trouble causing excessive wear on the shaft. When working under pressure there have been instances of water

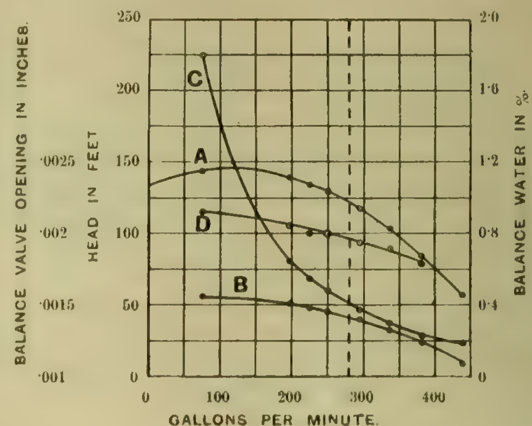


Fig. 16.

A Total head on pump in feet of water; B. Head in balancing chamber in feet of water; C. Amount of balance water; D. Movement of balance valve.

leaking past them and along the shaft into the bearing and floating the oil out of the bearing. These difficulties led the author to consider a design in which stuffing boxes at the delivery end of the pump were dispensed with entirely. This, of course, necessitated the use of some form of internal shaft bearing which must be so designed that the water with which the pump is dealing cannot pass along it. This is attained by the adoption of the design shown in Fig. 14. As this bearing has a closed end at E, no water can pass along it from the balancing chamber C. The bearing is supplied with a grease lubricant by means of a special lubricator. This lubricant, after traversing the whole length of the bearing, passes into the balance water. Incidentally it will be noticed that the water used for balancing flows round the outside of the bush, thus forming a water-cooled bearing. Not only does this type of bearing dispense with a stuffing box, but it allows a much stiffer bearing to be brought close up to the rotating impellers than is the case when an external bearing is used. This is clearly shown by a comparison between Fig. 14 and Fig. 17, which shows the same pump arranged with an external bearing. This type of internal bearing has, in actual practice, proved to be quite reliable even when running at high speeds.

In case of pumps which drive through the suction end, it is necessary to have a stuffing box working with a partial vacuum on the pump side. Unless special precautions are taken, air will be drawn into the pump with the risk of it losing its water. The usual practice is to arrange some form of water sealing. Fig. 1 shows one method in which water is taken from one side of the first impeller and led into a groove in the neck bush. This provides a complete water seal, and when running the gland should be left sufficiently loose to allow a slight drip of water showing that the water seal is operative, and that no air is being drawn into the pump. It is not, however, always advisable to seal the stuffing box with the liquor which the pump is handling, as, for instance, in the case of a pump dealing with a liquor which would have an injurious effect upon the packing and the shaft running in the packing. In cases such as this a separate supply of water is used, and led to the neck bush by some external means such as the funnel shown in Fig. 18.

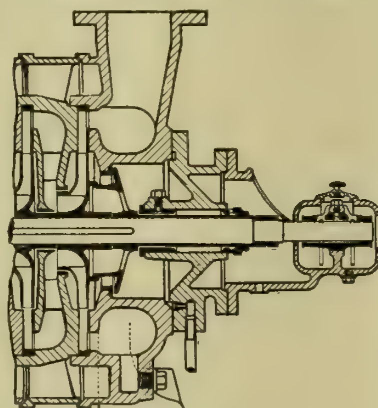


Fig. 17.

Another point of design which increases the reliability is that no small screws or similar fixings should be employed inside the pump. If these are used they are liable to work

loose, not only due to vibration, but also due to water getting to the threads and corroding them. All parts, such as the guide passages, should, with advantage, be held in place by means of the main bolts of the pump, as is the case in the pump illustrated in Fig. 1.

Before installing a centrifugal pump care must be taken to see that the total head including suction and delivery lifts and friction head is correctly estimated. This is particularly necessary if a pump is to be driven at a constant speed, such as is the case when an alternating-current motor is used for driving. Fig. 5 illustrates this point. The curves shown are taken from a pump designed to deliver 250 galls. per minute against a total head of 175ft. when running at a constant speed of 1,400 revs. per minute. Had the actual head been 185ft. the pump would only have delivered about 200 galls. per minute, and had the actual head been 200ft. it is clear from the curves that the pump would not have delivered any water. On the other hand, had the actual head been 155ft. instead of 175ft. the pump would have delivered an increased quantity of water, namely 300 galls. per minute, causing an increase of 9 per cent. in the power absorbed. It will be seen from this also that it is advisable to install a motor having a margin of power to prevent overloading should the actual head on the pump be lower than that for which it has been designed. In medium-sized motors it is usual to allow a 20 per cent. margin in power.

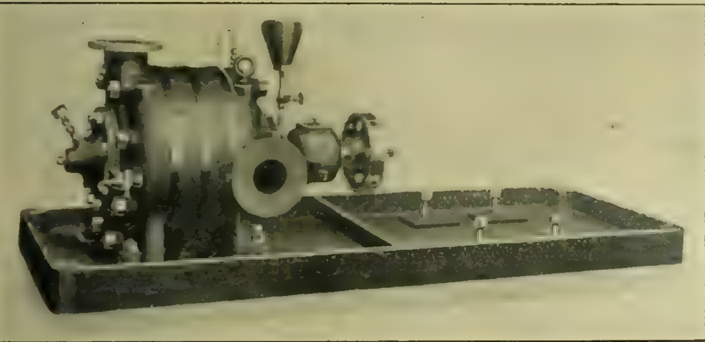


FIG. 18.

The size of suction and delivery pipes depends upon what is considered the most economical friction head in the case under consideration. In estimating the friction head it should be remembered that this head increases approximately inversely as the fifth power of the diameter of the pipe and that when dirty water is being handled due allowance should be made for the pipes becoming coated on the inside.

The question of the speed and number of stages of the pump to ensure reliability is one best left to the manufacturer, for obviously, when dealing with clean water much greater speeds are allowable without undue wear inside the pump taking place than when the water is charged with solid matter in suspension.

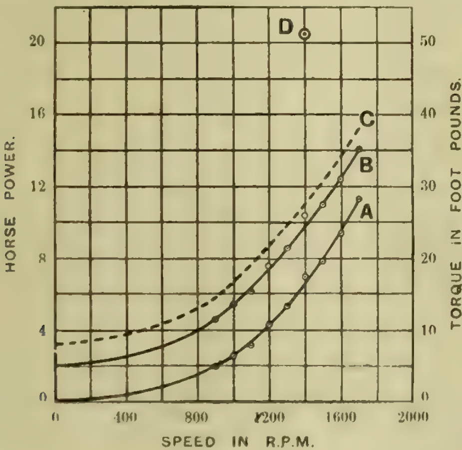


FIG. 19.

A. Horse-power; B. Torque corresponding to curve A; C. Total torque, including accelerating torque; D. Full load horse-power.

A centrifugal pump will, generally speaking, deal with as great a suction lift as a reciprocating pump, but, nevertheless, it is advisable to place the pump as near the source of supply as possible, for the less the suction the less the liability to trouble due to air leakage. In the case of hot liquids being handled the permissible suction lift is much reduced.

The suction pipes should always be laid with a rise towards the pump throughout the entire length so as to obviate any trouble due to air accumulating at any point.

A valve, preferably a sluice valve, should always be placed in the delivery main, as close to the pump as convenient, and for high lifts it is also advisable to fit a non-return valve in the delivery main. This prevents the column of water falling back on to the foot valve, which is possible, as there are no valves in the pump itself, and causing dangerous water hammer shocks in the pump if this be suddenly stopped for any reason.

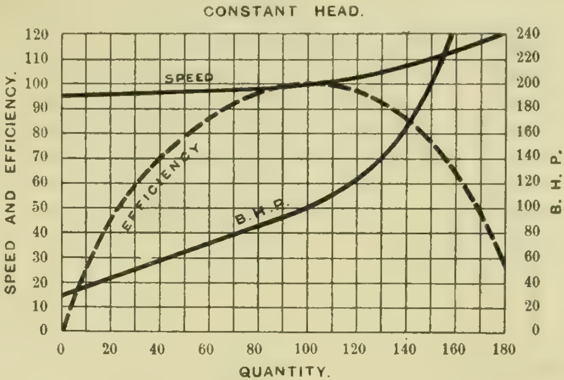


FIG. 20.

Some method of priming or filling the pump with water must be provided. This is usually done by allowing the water in the delivery column to run back past the delivery valve into the suction pipe and the pump forcing out the air through an air cock, which is fitted on the highest part of the pump. Should there be no water available in the delivery column the pump must be filled by hand or from some external water supply, or an ejector must be fitted which will draw out the air and allow the water to rise up the suction pipe into the pump.

In starting up a centrifugal pump, after seeing that the bearings are in order and that the pump is fully primed, the delivery valve should be closed and the pump run up to its proper speed. The delivery valve can then be slowly opened until the pump is discharging its full quantity. A glance at curves in Fig. 5 will show that no dangerous increase in pressure takes place when the pump is running with the delivery valve shut, *i.e.*, with the pump discharging no water.

The conditions imposed upon a motor in starting up a centrifugal pump are quite light, as the power required is practically nil at very low speeds, and gradually increases as the speed increases, reaching a maximum when the pump is running at its normal speed with the delivery valve closed, of a quarter to a third of the full load.

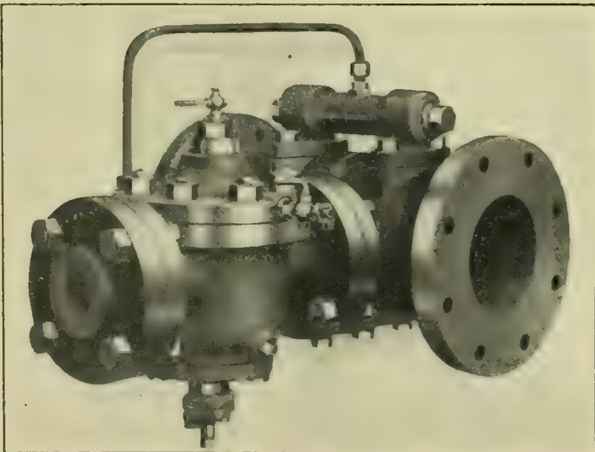


FIG. 21.

Fig. 19 gives a curve showing the horse-power required by an actual pump when running at different speeds with the delivery valve closed. The curve A represents the power

absorbed in overcoming mechanical and hydraulic friction and in setting up eddies in the water. The torque curve B corresponds to the power curve. This, of course, only represents the torque required at starting, providing the pump is brought up to speed slowly, as it takes no account of the

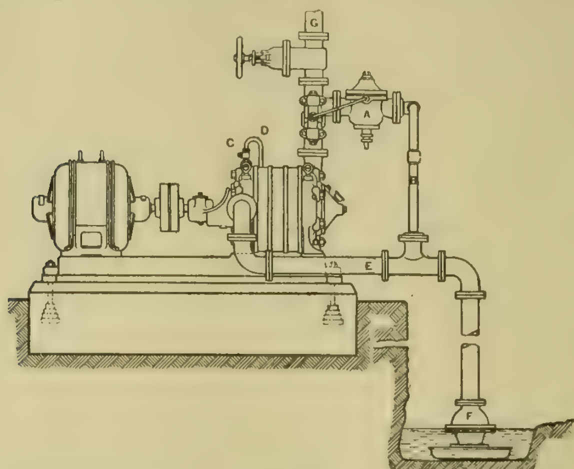


FIG. 22.

A. Automatic Priming Valve; B. Priming Pipe; C. Non-return Valve; D. Air Discharge Pipe; E. Suction Pipe; F. Foot Valve and Strainer; G. Delivery Pipe.

torque required to accelerate the rotating elements. The torque curve C is a corrected one, based on the assumption that this particular pump is taken up to its full speed in 10 seconds with a uniform acceleration.

Should it be necessary to reduce the quantity delivered by a pump when running under normal conditions, it is advisable to do this by partially closing the delivery valve, or in other words, by slightly increasing the head on the pump. This is quite an economical method of regulation. The quantity can be decreased by decreasing the speed of the pump, but this is by no means so reliable, as will be seen from Fig. 20, which shows the characteristic curves of a pump running under a constant head, the speed, quantity, power, and efficiency all being expressed as percentages of the normal conditions. It will be seen that a decrease in speed to 95 per cent. of the normal causes the pump to stop delivering altogether, and as this increase is so slight it is not a desirable method of regulation. The quantity can, however, be increased somewhat by increasing the speed.

To ensure reliability in actual working great care should be taken that no trouble is caused by air on the suction side of the pump. Should air leak through a bad joint in the suction pipe the pump will, sooner or later, lose its water, with the possibility of serious results owing to some parts running dry and becoming seized up. This may also happen should the end of the pump suction pipe become uncovered.

Fig. 21 shows a gear used for preventing trouble due to air leakage. Fig. 22 shows the arrangement of this gear on a pump, and Fig. 23 shows a section. The action of this gear is as follows: In the delivery main A, Fig. 23, there is placed a diaphragm B with an opening of such size as to cause a portion of the water to be by-passed through the pressure regulator C. This regulator consists of a venturi tube D having converging

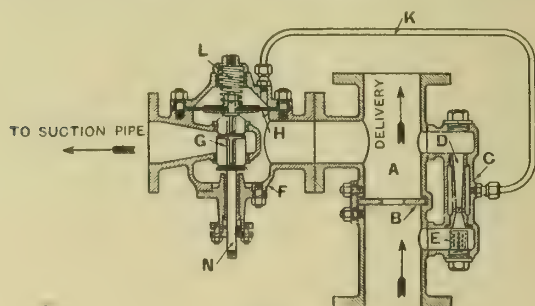


FIG. 23.

and diverging nozzles, the entrance to the converging nozzle being protected by a small strainer E. The priming valve F is attached to the delivery main, as shown, and contains a double beat balanced valve G, the operation of which is controlled by the movement of the rubber diaphragm H. The under side of this diaphragm is subjected to the pressure which obtains in the delivery main A, while the upper side is subjected to the pressure existing at the throat of the venturi tube D, since these are connected by means of the pipe K and the small holes drilled in the side of the venturi tube at the throat. The valve F is fitted with an external spindle N, so that its operation can be seen.

When the pump is delivering water some of this flows through the venturi tube and attains a high velocity through the throat, its pressure at this point being correspondingly reduced, with the result that the pressure on the top of the diaphragm of the valve becomes lower than that on the underside, and the valve is consequently closed against the action of the spring L. If air enters the pump the flow of water in the delivery main ceases, and also the flow through the venturi tube, with the result that the pressure at the throat becomes equal to that in the delivery main. The pressures on the two sides of the rubber diaphragm now being equalised the valve is opened by the action of the spring and the supply of priming water passes from the delivery main into the suction pipe, forcing out any accumulation air through an air discharge pipe fitted with a small non-return valve. Immediately this is done the pump picks up its water again, the flow through the delivery main and venturi tube is re-established, and the priming valve is closed as a result.

This gear can, with advantage, be fitted on pumps used for mine sinking purposes where it is desirable to keep the floor as dry as possible, since a pump so fitted can be allowed to run unattended as it will automatically reprime itself should the suction pipe become uncovered and air enter into the pump, which under ordinary circumstances would cause the pump to lose its water entirely.

There is no question but that at the present time if due attention be paid to the points raised in this paper centrifugal pumps can be obtained which are quite reliable in operation, but such pumps are not necessarily the cheapest in the first place, though they prove to be so in the end. It is, however, hardly possible for a manufacturer to turn out a pump which will give complete satisfaction unless this is installed, run, and treated with the respect due to a high-class, high-speed machine. Being pumps, by the very nature of things the conditions under which they have to work are usually severe enough at the best without making them worse by inattention.

In conclusion, the author wishes to express his thanks to Messrs. Holden & Brooke, Ltd., for permission to publish results of experiments and for the loan of blocks from which the illustrations have been prepared.

APPLIED STABILITY OF SHIPS.

A PAPER on "Applied Stability of Ships" was read by Mr. J. H. Heck on Monday, October 21st, at the Institute of Marine Engineers, Stratford, E. Mr. J. T. Milton (Chairman of Council) presided. In the course of his paper Mr. Heck said the art of making a ship stable really consisted in arranging and ensuring that the vertical line passing through the centre of buoyancy of any designed inclination would intersect the middle line of the vessel in a point, the height of which above the top of the keel was greater than that of the common centre of gravity of the ship and all it contained. The information required to determine the statical stability was: (*a*) the displacement; (*b*) the position of the centre of buoyancy line; and (*c*) the position of the centre of gravity. The two former could be obtained from particulars furnished by the drawings, and the values would remain the same during the life of the vessel. The real control of laden cargo steamers, however, was in the hands of the officers in charge, who, for that reason, needed at times some means of measuring the height of the centre of gravity, and the simplest and quickest way of arriving at this was by the operation of inclining. Side tanks in the double bottom could be used for this purpose at small expense, and as the moment produced by the tanks when full was known and constant, it would be possible to supply simple instructions in the form of tables, so as to place in the hands of superintendents and masters an easy and practical method of gauging and testing the vessel's condition in regard to stowage and stability. Mr. Heck gave specimen tables for a vessel of 7,840 tons load displacement, showing the mean draught of water, the angle of heel produced on the vessel by filling the trimming tank, the metacentric height corresponding to the angle of heel produced, and the

righting moment in foot-tons (corresponding to the various angles of heel produced) for the respective angles of inclination of 15°, 30°, 45°, and 60°. A note was also given at the foot of each table stating the angle of heel which should not be exceeded.

In opening the discussion, Mr. Jas. Shanks said the method put forward by Mr. Heck was simple and would give reliable results if it could be carried out accurately, but he doubted whether this could be done sufficiently carefully under present-day conditions of loading. He asked if allowance had been made for the effect of loose water, of which no ship was absolutely free. Mr. W. I. Steele was also of opinion that there would be little opportunity of taking inclinations while the ship was being loaded. Mr. J. Clark questioned the author as to the methods of arriving at the centre of gravity and metacentric height. He understood that a vessel with a high metacentric height was, in some weathers, almost as dangerous as a boat with a low one. He considered the idea of the trimming tank to be simple, and one which would prove effective. Mr. A. Robertson referred to the difficulties of carrying out the suggestions when at foreign ports. He thought that in many instances the water in the boilers would effect a variation in the centre of gravity which would produce an error in the calculations. He asked if the longitudinal metacentric height had any great effect upon the stability of ships at sea. Mr. F. M. Timpson was of opinion that it should be made as great an offence for a vessel to go to sea in an unstable condition as to go overloaded. Mr. Thomas referred to the high standard of the Board of Trade examinations for the extra chief engineers' certificates with regard to questions on stability. It would not be safe to say, even if a vessel had a negative metacentric height, that she was unsafe. The Chairman pointed out that the tables not only gave the metacentric height, but showed also how the righting moments increased as the heel increased. He thought the questions of free water and of using out the coal were calculable and could be allowed for. He suggested that a table might be prepared showing what the stability should be at a certain draught, when nearly loaded, as compared with that of the full draught when loaded. Mr. W. J. Dibb and Mr. John McLaren commented on the difficulties which might be experienced on putting the system into operation.

In replying, Mr. Heck said the paper was confined simply to cargo vessels, and not to the larger class of liners. The effect of free water could easily be determined. He said the inclination could be taken in about two hours, which would be amply compensated by the removal of many troubles due to instability. After describing graphically how his calculations were arrived at, he alluded to the importance attached to this subject to-day as compared with a few years ago, and expressed the view that such a method as he had outlined would be in general use before many years. A hearty vote of thanks was accorded to Mr. Heck, on the proposal of the chairman.

AUTOMOBILE PROGRESS.

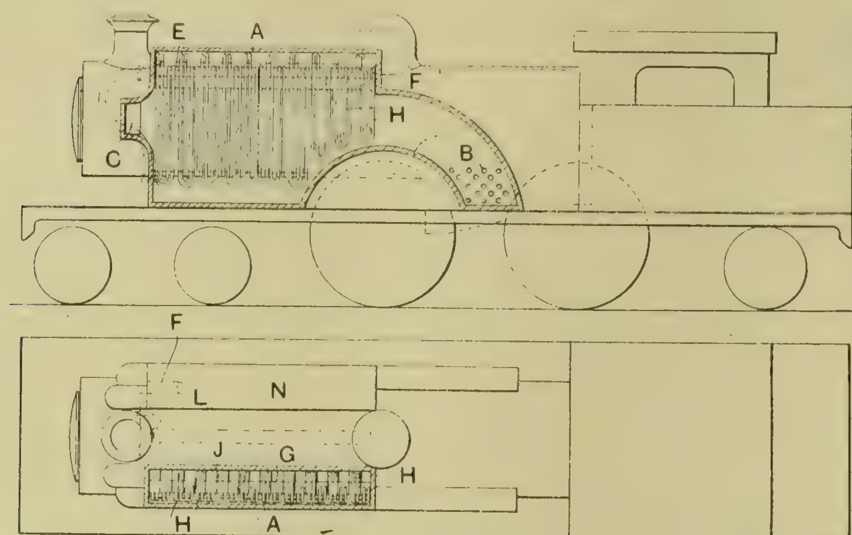
A REVIEW of automobile progress was presented by Mr. T. B. Brown in his presidential address, delivered before the Institution of Automobile Engineers. In London, he said, there were licensed during the year ending August 31st last 2,510 motor omnibuses, as against 533 drawn by horses; the motor-cabs licensed for the same period were 7,860, with only 672 hansoms and 1,982 four-wheeled horse cabs. The economy of motor-vans over horse traction had, he considered, been proved, and the reasons why they had not been produced in comparatively large numbers were, in the first place, not overmuch capital was invested in the production of commercial motor vehicles, so that makers were not generally in a position to give credit. Then it was impossible to use the automobile fully and economically where there was only work for a single horse. The great general carrier companies were using motor transport largely, as economies were attainable by large fleets of motor vehicles, as shown by the low cost of maintenance of large motor-omnibus and cab companies. The cost of running commercial motor vehicles was being continually reduced, especially where efficient organisation existed for maintenance in large numbers. One of the largest motor-omnibus companies had now reduced its running costs to 7½d. per car mile, whereas, in 1910, the figure was about 9d., so that the motor-omnibus was proving a formidable competitor to the electric tramcar. A new-comer in the shape of the electric trolley omnibus was well worth the attention of automobile engineers, as the greater part of the design and construction of these vehicles necessarily followed motor-omnibus rather than tramcar practice. Referring to motor-cycles, he said that this year had seen the production of several cycle engines with rotary valves, but these had not yet been placed on the market. Other noticeable features of the motor-cycle during the year were the almost universal use of the chain for transmission on high-powered machines, the fitting of clutches, a foot-starting device, and the wide use of change-speed gears.

The fuel question was, he observed, becoming serious, as the retail price of petrol had risen to 1s. 6d. per gallon, and likely to go higher, as the supply was practically controlled by one firm, which furnished about three-fourths of the total amount used. On this account the Royal Automobile Club was going carefully into the question of substitutes for petrol spirit, and it was proposed to undertake tests of all kinds—solid, liquid, and gaseous. The various grades of paraffin, crude oil, mixtures of petrol and kerosine, naphthaline, benzol, and alcohol had all been tried to a certain extent. Naphthaline and benzol formed excellent substitutes for petrol, but the supply was limited. The disadvantages of paraffin so far had been the smell from the exhaust, its well-known tendency "to creep," and the carbon deposit left in the combustion head whenever the mixture was imperfect. Excellent results had so far been obtainable with paraffin with engines running on steady loads, but the irregular load of an automobile engine had proved a serious obstacle to the proper carburation of paraffin and heavier oils. There was also the possibility that the price of any substitute would rise as soon as the demand for it became great, just as had been the case with the price of the heavy oil used in the Diesel engine, which was sold not so long ago at 38s. per ton, whereas it had now risen to over 80s. per ton. The use of solid fuel in the shape of carbon had been proposed for automobiles, and at least one vehicle had been built with a suction gas producer. An automobile using paraffin had covered 2,000 miles under official observation—half on the road at a consumption of 35·7 ton-miles per gallon, and the other half on the Brooklands track at 35 miles per hour and 36·9 ton-miles per gallon.

At the British Association Dr. Dugald Clerk, F.R.S., brought out the difference in time taken to explode a gas when in a state of turbulence and when in comparative rest. In the experiments a fan was used to create a turbulence on a 10 per cent. mixture of coal gas and air, with the result that the time of explosion was shortened from 0·13 sec. to 0·03 sec. when the speed was raised from 2,000 to 4,500 revs. per minute. This accounted for satisfactory ignition with motors running at high speeds, and Dr. Clerk was to be congratulated on having made this interesting discovery. The possibility of using the turbine for internal combustion was referred to by my predecessor in his address, and, so far, there did not appear to be much hope for a practical issue, principally due to the impossibility of finding a material able to withstand the enormously high stresses and temperatures involved if reasonable economy was to be attained. Experiments had been made with various types, the most hopeful suggestion being that of using the explosion to give velocity to water, the result being a combined water and gas turbine. Die-finished castings, now coming much into use, had given an enormous advantage to the firm in a position to manufacture large batches.

The so-called American invasion of the light, cheap car fitted with a comparatively large engine had, he remarked, found a ready market here, but it had not materially affected the demand for the various types manufactured in this country. Noise reduction had become more difficult, with the rise of pressures and increase in size of valves. Since the introduction of the sleeve valve many attempts had been made to devise new systems of valve motion, many being merely revivals of old methods already discarded by gas-engine makers. Attempts to use piston valves had been made, but in some of these the piston valve heads were exposed to the explosion pressure, so that severe reversals of stress were put upon the valve mechanism, producing undue noise. Rotary valves were being tried, but difficulty must be experienced in obtaining a gas-tight joint, especially in those where the same rotary part was used for inlet and

exhaust passages, as the constant warping was bound to cause leakage. The difference between the temperature when starting from cold and that when running would result in expansion of the parts which were not water-cooled. There was much in favour of the rotary valve, as in any type of reciprocating valve, whether poppet, sleeve, or piston, there was bound to be noise as soon as the slightest wear of the valve-driving mechanism occurred. With the introduction of very light steel pistons, another source of noise occurred in



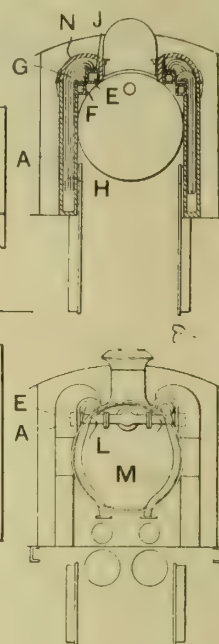
Superheater for Locomotives.

their tendency to tap against the side of the cylinder, and an attempt had been made to get over this by cutting slots in the skirt of the piston. The most troublesome noises in transmission were caused by change-speed gear wheels. Ball bearings intensified the trouble, as plain bearings did not conduct the sound emitted by gear wheels to so large an extent as ball bearings. Some experiments conducted by the author with ball-bearing cam shafts several years ago bore this out to a surprising degree. A successful attempt to overcome the difficulty on omnibuses had been made by the use of short chain drives in lieu of the spur gears, and several firms were now adopting this system for passenger cars. A light car with variable friction drive was being manufactured, the two friction discs, placed at right angles, being composed of hard and soft steel respectively. In driving the car care had to be taken to prevent the discs slipping, or a flat was likely to be produced on the wheel whose edge impinged on the face of the other disc.

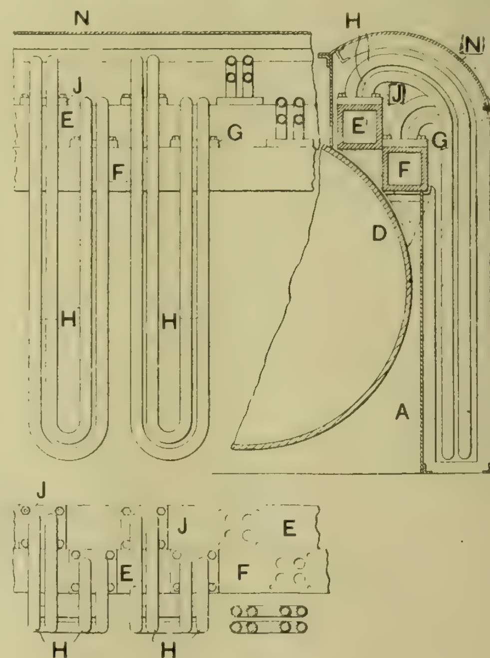
Several petrol-electric systems were in use, and were giving most satisfactory results for omnibuses and other heavy vehicles where the weight of the dynamo-electric machinery was not too large a proportion of the whole. A consumption of 58 ton-miles per gallon was obtained with one petrol-electric system in a recent R.A.C. test of 2,000 miles on ordinary roads. Hydraulic systems of variable gear had not yet come into general use, though several showed considerable promise in the experimental stage. While the chain drive had almost disappeared in the ordinary pleasure car, it was still the most popular for heavy commercial cars, due to the difficulty of obtaining the necessary reduction in the gear, which was not possible in a single pair of bevel wheels. For heavy lorries worm gear did not seem to be making the progress which appeared likely, and the probable reason was, in his opinion, the difficulty in lubricating the rubbing surfaces of the wheel where the pressures were high. This difficulty was, of course, not insurmountable, and it might very probably be found that forced lubrication would overcome it. One great advantage of chain drive was the excellent clearance it provided under the rear axle. One of the most difficult problems was the lubrication of the cylinder. The slightest excess of oil resulted in unpleasant odours from the exhaust and carbon deposits on the combustion heads and piston tops. There should be no excuse for any emission of unpleasant exhaust. A certain mixture too rich for perfect combustion gave more power than the perfect, but the gain was so slight that it was not worth using for any but racing purposes, and it had the disadvantage of increasing carbon deposit.

SUPERHEATER FOR LOCOMOTIVES.

A design of superheater for application to locomotive engines, the invention of Ferguson Superheaters, Ltd., 11, Queen Victoria Street, London, is shown in the accompanying illustrations. In this arrangement the superheating tubes are in independent sections or groups, connected at their ends to removable cover plates closing over openings in the top of inlet and outlet steam headers. Two casings A are arranged on each side of the boiler, as shown. The furnace gases are admitted to the rear end of each casing through hollow tubular stays B, and pass off from the front end of the casing to the smokebox through the passage C. As shown, the bottom of the casing is made to rest on the top of the main horizontal longitudinal frame of the engine. The upper end of each casing is enlarged so that it extends inwards for a distance over the top of the cylindrical shell of the boiler. D is a bracket curved to conform to the exterior of this portion of the shell of the boiler and secured to it. The bracket is formed with two shelves, one at a higher level than the other and in rear of it so as not to overlap it. Upon each shelf is placed a header; the header E



on the upper shelf is clear of the header F on the lower shelf, so that the cover plates G which close over openings in the top of this latter header can be removed without being interfered with by the header E. The superheating pipes H are each connected at one end to one of the cover plates G, and at the opposite end to one of the cover plates J secured to the top of the header E. Each cover plate has four



Superheater for Locomotives.

superheating pipes secured to it. As shown, the superheating pipes rise upwards from the cover plates J, are bent forwards and then downwards and made to extend nearly to the bottom of the casing, where they are bent back towards the rear or towards the front end of the engine and then bent upwards and made to extend to the upper part of the casing, where they are bent over and secured to the cover plates G. Steam is supplied to the front end of the headers F through pipes L, and is led away from the front end of the headers E through pipes M to the cylinders of the engine. A hinged door N is provided, closing over the top of each casing A.

INDUSTRIAL AND TRADE NOTES.

Proposed Railway Development in Victoria.—There are 318 miles of State railways almost completed and open for traffic in Victoria, with a further 186 miles under construction, and 83 miles authorised but not yet begun. Schemes for further lines are under consideration representing a total length of about 430 miles and involving an expenditure of £1,550,000.

New Vessel for the Cunard Line.—It is understood that the Cunard Co., of Liverpool, are inviting tenders for an intermediate passenger steamer of the "Laconia" and "Franconia" class, both of which vessels are of 18,000 tons, and were built at the Wallsend shipyard of Swan, Hunter, & Wigham Richardson, Ltd. In addition to the Wallsend firm, another Tyne shipbuilding company has, it is stated, been asked to quote for the new vessel.

Proposed Amalgamation of London Tube Railways.—It is officially stated that the directors of the Metropolitan Railway Company and the Great Northern and City Railway Company have come to an agreement, by which, subject to Parliamentary sanction and the approval of the stock and shareholders, the Metropolitan Company takes over the Great Northern and City Railway as a going concern as from the 30th June next.

Scottish Tube Trade.—The directors of the Scottish Tube Company have decided to spend £70,000 in the extension of one of their principal tube manufactories situated in the eastern quarter of Glasgow, adjoining the River Clyde. The works are those that belonged to Messrs. Eadie previous to the arrangement of the combine, and already occupy a very large area, and have a heavy output. The tube trade in Scotland at present is excessively busy.

Shipbuilding Orders.—The Pacific Steam Navigation Company has, we learn, just placed with Messrs. Harland & Wolff, Belfast, orders for five new vessels, which will be about 550ft. long, with a gross tonnage of between 11,000 and 12,000. It is expected that one or two of these vessels will be built on the Clyde. Messrs. Workman, Clark, & Co., of Belfast, have also received orders for two vessels of the intermediate type from the Royal Mail Steam Packet Company. These will be of similar size and design to the Pacific Company's vessels.

Hull and the Oil Trade.—An important development in the import trade of Hull is an undertaking by the North-eastern Railway Company to construct at Saltend in the Humber an oil harbour, with jetties for the discharge of oil steamers. The new harbour will be devoted to the importation and storage of petroleum, and the jetty will be accessible to tank steamers at all states of the tide. The harbour will be connected with the North-eastern Railway main system by a branch railway. The Humber Conservancy Board have sanctioned the company power to carry out the necessary dredging. Hull is likely to become an important oil-distributing centre for the North of England.

Colliery Rescue Stations.—The Durham and Northumberland Coal Owners' Association were among the first to install a thoroughly up-to-date fire and rescue station. This is located in Scotswood Road, Newcastle-on-Tyne. Three additional stations are, we learn, shortly to be installed covering various collieries within 60 miles radius of the head station, and an order has been placed for three Merryweather Hatfield petrol motor fire engines. They will be of the same design as the one at Newcastle, but of smaller size, with pumps of a capacity of 350 gallons per minute. These engines can travel at over 30 miles an hour on the level, and the pumps can be brought into service immediately on arriving at the scene of action.

New Thames Tunnel.—A new Thames tunnel was opened on Saturday last, making the fifth passage which London now has under the river. The new tunnel is between North and South Woolwich. The thickness of the river-bed above the tunnel is about 10ft. The tunnel has taken over two years to complete, although the actual tunnel length was started in December, 1910, and finished in October, 1911. The cost has been about £85,000. Access to the tunnel is obtained by lifts holding 40 persons each, and also by spiral staircases. Blackwall tunnel cost a million and a half. The Rotherhithe tunnel cost £1,000,000, and that at Greenwich £180,000. Blackwall and Rotherhithe tunnels are for vehicular traffic as well as foot passengers.

Proposed Railway Development in China.—H.M. Legation at Peking, report the publication of a Presidential Order, dated September 9th, empowering Dr. Sun Yat Sen to form a railway corporation for the purpose of financing and constructing a railway system throughout China. Dr. Sun proposes to construct some 70,000 miles of railways in 10 years, at a capital cost of £600,000,000 by means of concessions granted to foreign capitalists to build the railways and work them for a period of 40 years. At the end of that time they would revert to the Chinese Government without payment. The scheme includes trunk lines between Kuangchow and Cheng-tu; Kwangchow and Ta-li (Yunnan); Nanchou and Chungking; the mouth of the Yang-tse-kiang and Ili; Taku and Canton-Hongkong; and between Tientsin and Manchuria.

Rules for International Exhibitions.—An international agreement for the regulation of exhibitions was signed on the 26th ult. at the International Exhibitions Conference, held at Berlin. One of the most important provisions of the agreement is to the effect that the contracting States may in future take part only in universal exhibitions at intervals of not less than three years, and of 10 years in any one country. A precise classification determines which international exhibitions shall be regarded as official or officially recognised. Certain rules are also laid down for the style of invitations to such exhibitions, their organisation, duration, the arrangement of the foreign sections, and specially for the composition and procedure of the court of awards and the distribution of the diplomas. The agreement further contains provisions for combating bogus exhibitions and traffic in medals.

Motor Vehicles in France.—A British official report states that the development in the total number of motors of all kinds has increased enormously in France. In 1900 there were only 2,354 private motors in use in the whole of France. By 1907 the number had risen to 31,295, and the return for 1910 gives the figures 53,669. The number of motor road 'buses is also rapidly developing, while the greater part of the numerous big shops have now adopted motor-vans and other smaller motor vehicles for the delivery of goods. The makers of motor conveyances were considerably injured by the economic crisis of 1907, and they then realised that it would be necessary to direct their attention largely to the manufacture of light and economical small motor-cars, especially for all kinds of industrial purposes. The result of this policy is shown by the figures of 1910, when out of a total of 53,669 cars, over 25,000 cars belonged to this cheaper class as opposed to so-called motor-cars "de luxe." France does not import a large proportion of such cars. Its manufacturers not only supply the greater part of the home demand, but they also export a great number. The chief countries to which they are exported are as follows, in the order of their importance: The United Kingdom, Belgium, Germany, and Italy.

English Motor Manufacturers and American Motor-cars.—Mr. Albert Halstead, the United States Consul at Birmingham, in a report to Washington, remarks that the whole tendency in the automobile line is towards the development of efficient cheap machines with excellent wearing qualities, adding that American cars of low price have had a very large sale, and have spurred British manufacturers on to making automobiles at nearly the same price, but of engine and body design more calculated to please British taste. Next year, it is understood, a number of such cars will be on the market, and already one company has introduced a car at a comparatively low price and of attractive body design which has met severe tests satisfactorily. Commenting on this, the Consul says the information is interesting as indicating the readiness of British manufacturers to copy a type of vehicle introduced from abroad when the vehicle has met with success in Great Britain. The foreign manufacturers thus incur the expense of the introduction, and the British makers, after awaiting the results of such experiments, take advantage of the foreigners' experience, astutely modify the designs so as to more exactly meet with British ideas, and enter the market backed by the national preference for articles of domestic origin. This does not indicate, of course, that the British motor industry has in any sense been built through copying foreign ideas and designs (though it has been greatly assisted thereby), for many improvements and niceties of adjustment on automobiles and commercial motor vehicles are due to the ingenuity of British inventors and designers.

Aeroplane Engines.—The judges in their report on the military aeroplane competition held at Larkhill point out that all the aeroplanes which passed the tests and others recommended for awards were fitted out with foreign engines and remark: "The longer period of development abroad, which has standardised certain foreign engines, has been greatly in favour of foreign manufacturers, as there is a prospect of purchasers obtaining their engines on a definite date, and of their conforming to a general standard. Although the promise of the four types of British engines entered in the competition is hopeful, they have not yet proved themselves capable of equalling the performances of the best foreign high-power engines." The judges add: "The importance of encouraging or establishing a first-rate British aircraft engine industry cannot be over-rated."

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 58, New Bailey Street, Manchester.

MECHANICAL, 1911.

Driving mechanism for internal-combustion engines. Paduvani. 15755.
Fuel. Clarke & Campbell. 15837.
Internal-combustion engines. Martinel & Huxley. 21820.
Acetylene generator. Jackson. 21836.
Apparatus for bending tubes. Sibley. 21847.
Double-acting internal-combustion engine. Rigaud. 21990.
Automatic feeding devices for gas generators. Hart-Bayes. 22026.
Apparatus for generating and burning oil gas. Orr. 22036.
Anti-friction bearing. Wheatley. 22142.
Cranes. Welin. 22221.
Crossheads. Prince. 22246.
Percussive tools for scaling tubes. Clements. 22310.
Internal-combustion engines. Lines & Lines. 22348.
Tube or pipe-jointing apparatus. Whitehead. 22515.
Inlet and exhaust valves for internal-combustion engines. Borner. 22527.
Acetylene gas generating apparatus. Todman. 22551.
Pistons of explosion engines. Brown & Clement Talbot, Ltd. 22561.
Centralising gear for railway buffer couplings. Watson. 22621.
Flexible transmission mechanism. Bowden Wire, Ltd., and Larkin. 22638.
Rotating cylinder internal-combustion engines. D'Albay, and Soc. Houdaille et Sabot. 22766.
Means for balancing aeroplanes. Wanzer. 22829.
Separation of gaseous mixtures. Lilienfeld. 22930.
Process for effecting the adherence of copper and its alloys to the surfaces of iron and steel articles and for uniting iron and steel plates to one another. Clark. 22982.
Means for controlling the supply of fluid to winding engines. Cockburn & MacNicoll. 23163.
Rotary explosion engines. Iochum. 23208.
Steam superheaters. Thomsen. 24240.
Carburetters for explosion motors. Soc. du Carburateur Zenith. 24932.
Internal-combustion engines. Davidson & Larmuth. 25289.
Screw propellers. Mueller. 25330.
Propellers. Bevis. 25567.
Piston valve for locomotive engines. Robinson. 25656.
Moulds for forming journal or bush bearings. Plant. 26895.
Propellers for ships. Heathcote & Weatherby. 27295.
Foundry moulding machines. Smith. 27724 and 27726.
Apparatus for grinding-in valves. Marles. 28419.
Automatic couplings for railway vehicles. Hubner. 28468.
Steam-condensing and vacuum-producing apparatus. Morison. 28679.
Steam generators. Steinmuller. 28746.

1912.

Valve mechanism for internal-combustion engines. De Richelle. 681.
Cam-valve gear for internal-combustion engines. De Richelle. 682.
Explosion engines. Barriere. 1868.
Valve grinding tool for use with internal-combustion engines. Stephens. 1887.
Process for manufacturing compound steel plates, armour plates, and hollow bodies. Braun. 2021.
Carburetters for internal-combustion engines. Brown, and Brown & Barlow, Ltd. 2305.
Internal-combustion engines. Jackson. 3002.
Turbine compressors or pumps. Lawaczeck & Aerzener Maschinenfabrik Ges. 3525.
Propellers. Espinosa & Vinay. 4810.
Steam generators. Schwab. 6767.
Percussive rock drills. Drinnan. 7085.
Flexible power transmission shafts. Grice & George Anderson and Co. (1905). 7176.
Multi-cylinder internal-combustion engine. Allgemeine Elektricitats Ges. 7246.
Lubricator pumps for locomotives. Benedetti. 8717.
Means for starting internal-combustion engines. Stuart. 8959.
Railway rail joints. Young. 9003.
Automatic drop-valve gear for steam engines. Beya. 9194.
Process for the manufacture of armour plates. Soc. Anon. Italiana Gio. Ansaldo Armstrong & Co. 9512.
Reciprocating engines having curved cylinders. Price. 9629.
Marine boilers. King. 10465.
Drain and relief valves for condensing steam engines. Davidson and Larmuth. 12420.
Rotary internal combustion engines. Sanchez & Baradat. 12447.
Pipe connections or couplings. Schulz. 14095.
Device for fixing and maintaining hermetic packings for the rotary valves of internal-combustion engines. Tartrais. 14117.
Method of manufacturing lubricating oils. De Hemptinne. 15035.
Screw propellers. Bedour. 15661.
Calorimeters for fluids. Kilburn. 17222.

ELECTRICAL, 1911.

Circuit interrupters. Harris. 21903.
Telephone switchboards. McLarn. 22046.
Couplings for electric conductors. Buckland. 22138.
Electric signalling apparatus for telephones. Nash & Western Electric Company. 22238.
Signals for use in wireless telegraphy. Angelini. 22443.
Telephonic transmitters and receivers. Marr. 22582.
Ohmmeters. Record. 22740.
Windings of electric generators. P. R. Jackson & Co., and Ainsworth. 23548.
Electric water heater and steam generator. Nichols. 24436.
Electrically-operated motor vehicles. Crompton & Co., Macfarlane, & Burge. 24778.
Pawls of electric controller regulators. Smith, Fleming, and Guerin. 26291.
Electrically-operated motor-vehicles. Crompton & Co., Macfarlane, & Burge. 26408.
Electric welding machines. British Thomson-Houston Company. 26645.
Audible electric signalling devices. Rogers. 26909.
Dynamo-electric induction machinery. Akt.-Ges. Brown, Boverie, et Cie. 28383.

1912.

Vapour electric apparatus. Hewitt. 183.
Electric power factor indicators. British Thomson-Houston Company. 193.
Contact apparatus for electric indicators for indicating the direction of rotation of a shaft. Molinari. 2355.
Electric heating element. Dowsing & Huntley. 3253.
Transmitter for printing telegraph systems. Etienne. 4585.
Time-controlled mechanism for electric switches. Haddan. 5985.
Electrically-actuated pumps. Richardson. 6004.
Multiple control of electric motors. Richter & Maffei-Schwartzkopff-Werke Ges. 6624.
Automatic protection device for electric circuits. Levy & George. 8590.
Apparatus for controlling direct-current electric motors. Siemens Bros. Dynamo Works, and Lydall. 9876.
Electrically-driven developing apparatus chiefly for writing telegraphs. Rappenecker. 13328.
Protecting devices for telephone apparatus. Siemens, and Halske Akt.-Ges. 13853.
Dynamos. Allgemeien Elektricitäts-Ges. 15589.
Electrical measuring instruments. Fauvin, Amiot, & Cheneaux. 18214.

METAL QUOTATIONS.

TUESDAY, OCTOBER 29TH.

Aluminium ingot	82/- per cwt.
" wire, according to sizes, &c. ......from	102/- "
" sheets " " ...... "	120/- "
Antimony ......£39/-/- to	£40/-/- per ton.
Brass, rolled	9⅛d. per lb.
" tubes (brazed)	11¾d.
" " (solid drawn)	10d.
" " wire	9⅛d.
Copper, Standard	£75/5/- per ton.
Iron, Cleveland	66/6 "
" Scotch	72/6 "
Lead, English	£19/15/- "
" Foreign (soft)	£19/7/6 "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£8/-/- per bottle
Silver	$29\frac{3}{16}$d. per oz.
Spelter	£27/10/- per ton.
Tin, block	£231/-/- "
Tin plates	15/6 "
Zinc sheets (Silesian)	£31/5/- "
" (Stettin; Vieille Montagne)	£31/10/- "

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Gas v. Electricity for Street Lighting.

THE competition between gas and electricity for lighting purposes has been long and strenuous and punctuated with interesting ups and downs, and though the advantage seems for some time to have been setting in favour of electricity, the struggle cannot yet be said to be finally decided. Probably it never will be, and each agent will be able to claim superiority in certain directions. For some time an experiment that has excited considerable interest in both gas and electric circles has been in progress in Manchester, where two adjacent lengths of thoroughfare in Princess Street and Portland Street have been illuminated, the one with high-pressure gas (at a pressure of 50in. to 60in. of water) and incandescent mantles, and the other with flame arc lamps. For the purpose of instituting as far as possible an exact comparison, two experts, Mr. Haydon T. Harrison and Mr. Jacques Abady, were appointed by the Manchester Corporation to make a joint investigation of the two systems and report on their respective merits. As the experts may be said to approach the question from its two opposite sides, their conclusions are particularly interesting, and illustrate how difficult it is, even with every desire to do so, to make reliable comparisons. In their joint report the two gentlemen agree: (1) That for all practical purposes the degree of illumination in the two streets is approximately equal. (2) That, based on figures of costs of current and gas given by the respective departments, the arc lamps as used are provided at annual cost which is less than the high-pressure gas lamps. (3) That the comparison between the possibilities of the two methods of lighting are vitiated by the fact that the gas lamps are giving an efficiency below similar lamps when properly installed and adjusted.

These conclusions seem to leave the relative merits of the two methods open to some doubt, but this joint report is accompanied by two individual reports, and that presented by Mr. Harrison has been hailed by the electrical press as irrefutable proof of the superiority of electricity. A perusal

of his figures certainly seems to leave little doubt as to the ultimate issue, though Mr. Abady's comments on certain aspects of the question show the danger of jumping to conclusions in comparing relative costs. Mr. Harrison arrives at a consumption of 79·5 cub. ft. per hour for each gas lamp, costing for high-pressure gas 1·147 pence per hour, which, added to cost of mantles, globes, labour, &c., brings up the cost to 1·5 pence per hour, as compared with a cost of 0·7 pence per hour for electric lighting for all-night lamps, or 0·9 pence for half-night lamps. In other words, 1½d. per hour only gives 1,750 candle power with gas, while it gives 6,354 candle power with electricity, or, put in another way, whereas 2,970 candle power would only cost ·7d. per hour with electricity, it would cost 2·54d. per hour with gas. These figures are so strikingly divergent that, as we have remarked, gas would seem to have no chance, even when big allowances are made for the admitted imperfections in its installation and adjustment. Nevertheless, it is desirable to glance at some observations and figures in Mr. Abady's report, since they show how easily comparisons in costs and methods of illumination may mislead when the efficiency and economy factors do not rest on the same basis. The gas high-pressure lamps, he points out, have an efficiency of only 27 candles per cubic foot of gas instead of 50 candles, as, he affirms, they would have if properly adjusted and supplied at suitable pressure. His comments on the figures of cost supplied as a basis of comparison also deserve noting. The electricity costs, he points out, are worked out on a basis of load factor and division of fixed and running costs, and arrived at after certain deductions made on account of traction current supplied from the power station, the net effect of which, he states, is to reduce the cost of lighting current at the expense of traction current. It is impossible to say how far this affects the comparison, but obviously it cannot be ignored, and it certainly is difficult to reconcile, as Mr. Abady remarks, the charge for traction of 1d. per unit on a 36 per cent. load factor (no profit) with the charges of 0·682d. per unit on a 45 per cent. load factor and 1·132d. on a 23 per cent. load factor. These are intricacies of departmental finance which may be capable of explanation, but without it they seem to favour electricity in any financial comparison with gas, especially if, as he affirms, the electricity renewals fund is below proper standard, while the gas department is in a strong financial position, having contributed during the last 10 years over £600,000 in aid of the rates, as against £73,500 by the electricity department. In any case, the figures and comments are instructive, and if they do not, after making every allowance, affect the conclusion that electricity is a more economical illuminant than gas for street purposes, they show at least the difficulty of presenting the facts accurately.

Oil Fuel for Power Purposes.

MR. C. E. STROMEYER, chief engineer of the Manchester Steam Users' Association, in his annual memorandum gives one or two interesting notes on the comparative values of oil and coal when used for producing steam or power. The coal strike last year brought the matter prominently before the attention of many steam users, and a good deal of loose talk, as is usually the case in times of excitement, was indulged in by the daily press. The substitution of oil for coal, except in special cases, is, as everyone who has given the slightest attention to the subject knows, pure chimera, as, apart from any question of economy, the world's output of oil would only meet about 5 per cent. of the requirements now met by coal. If used in internal-combustion engines it might be equivalent as a source of power to 15 per cent., but then only a small proportion of crude petroleum can be regarded as available for use in this way, and by far the larger part is utilised for illuminating or lubricating purposes. Comparisons of the relative values of oil and coal are not easy to make. Coal prices range, according to quality and locality, from less than 10s. for slack near the pit to over 20s. for good coal in towns. The following table, however, given in the memorandum serves roughly for the purpose of comparison and shows the extent to which the price of good coal would have to rise before it would be commercially possible to burn crude oil in its place :—

Relative Prices of Oil and Coal if Equal Economical Results are to be obtained.

Crude oil, per ton ..	Shillings	35	40	45	50	55	60
Crude oil, per gallon	Pence	1·75	2·0	2·25	2·5	2·75	3·0
Good coal, per ton	Shillings	26	30	34	38	41	45

A glance at the above figures shows how enormously the price of coal would have to rise, or vice versâ, the price of crude oil would have to fall, before it would be profitable to burn the latter, while, even if the prices of coal harmonised, oil is not quite so advantageous in some ways as might appear. Its thermal efficiency is high, but at best this only allows of a gain of about 5 per cent., and against this, as Mr. Stromeyer reminds his readers, have to be set the disadvantages usually associated with high efficiencies and high furnace temperatures in the form of overheating troubles, especially if the feed-water is sedimentary or greasy. It is true that oil firing permits of labour saving as regards furnace attention, but, on the other hand, it necessitates the use of special brick-lined chambers, which must be more or less dismantled annually, and thus cause expense, in order to comply with the requirements of inspection under the Factory and Workshops Act. For purposes of power production oil of course may be used directly in the engine, and as these are approximately about twice as efficient as steam engines, and as crude oil is about 37 per cent. better than good ordinary coal, it would mean that only about three-eighths of the weight of coal required in a first-class modern steam engine, or, say, ·6lb. of oil per brake horse-power, would be required in an internal-combustion engine. With the latter of course there are no boiler radiation losses at night, and thus the comparative quantity may be taken at ·5lb. per brake horse-power. Engines working with producer gas have about the same efficiency as oil engines, but as there is a loss of about 20 per cent. in producers, even if working continuously, and a further loss if they stand idle over night, their efficiency cannot fairly be taken as more than 40 per cent. better than the steam engine. On this basis Mr. Stromeyer has compiled the figures in the accompanying table, which, if not exactly accurate, at all events provide an instructive illustration :—

Relation of Prices of Oil and Coal used in various Engines.

	Per ton.					
Crude oil for Diesel engine ..	35/-	40/-	45/-	50/-	55/-	60/-
Petrol oil for Diesel engine ..	44/-	50/-	56/-	62/-	69/-	75/-
Coal for producer gas engine ..	11/6	13/6	15/-	16/6	18/6	20/-
Coal for gas-fired boiler	8/6	9/6	10/6	12/-	13/-	14/-
Coal for steam engine	10/-	12/-	13/6	15/-	16/6	18/-

In connection with possible installations of oil or gas in textile mills and workshops, it has to be remembered further that heat is often required for ventilating and manufacturing purposes in addition to power, and if a boiler is required it may for many reasons be preferable to make it large enough to drive the engine or to be associated with one or more others which can all be worked by one stoker, and taken all round, no method is more reliable or freer from trouble.

The Working of Chemical Stills.

The distillation of substances is a conspicuous feature in connection with chemical works and as a rule their operation is attended with no risk, the substance being boiled in a pan at atmospheric pressure and the vapour driven off and condensed in some convenient way, which renders increase of pressure in the boiling vessel impossible. This freedom from risk in working is, however, by no means universal, and it is well that chemical manufacturers should recognise this. Some of the most terrible explosions we can recall have occurred from the bursting of tar stills, which used to be unprovided with any safety valve or other means of relief in the event of the condensing worms becoming choked with wax, as they were liable to be unless carefully watched, in which event there was a risk of pressure accumulating, and, if not arrested, bursting the still, with terrible consequences, owing to the inflammable nature of the contents. It was, in fact, only after a number of such explosions that the need for a safety device of some kind became generally recognised by tar distillers. Tar stills, however, are not the only vessels which call for safety appliances. There are many other substances, the distillation of which gives rise to risk in distilling operations through deposit forming in the pipes leading to the worm or condenser and in all such cases some safety or relief device should be applied to the vessel in which the material is being boiled. A reminder of this fact is afforded by a report just issued by the Board of Trade on the explosion of a Diamine still at a chemical works at Clayton, near Manchester, on May 28th last. In this instance it appears that owing to the substance in the still boiling over, solid matter was deposited in the lead coil pipe of the worm and blocked the thoroughfare so that the apparatus, which was normally an open kettle, became hermetically sealed, with the result that the pressure accumulated, blew off the lid of the pan, and showered the scalding contents on three men who were near, injuring one so badly that he died. As the vessel was not intended to carry pressure, it was not fitted with any pressure gauge or safety valve, so that although the blocking of the pipe had been detected and the consequent danger realised, its magnitude was not indicated. It is to be trusted the case will serve as a warning to other chemical manufacturers of the necessity of so arranging pans of this kind that accumulation of serious pressure is impossible, either by fitting some simple relief valve, or so arranging the cover of the pan itself that it will lift off in the event of the free egress of the vapour through the condensing worm being impeded, while the fitting of a pressure gauge is a wise precaution in any case.

DYNAMICS OF TRAIN MOTION.

A paper entitled "Some Characteristic Dynamical Diagrams for the Motion of a Train during the Accelerating and Retarding Periods" was presented by Prof. W. E. Dalby at a meeting of the Institution of Mechanical Engineers held on October 25th. The author pointed out that the general development of electric traction for the purpose of operating suburban services was largely due to one important difference between the steam and the electric locomotive. In the case of the former the power was limited to that of the boiler which the locomotive carried, and this was strictly limited in size by the construction gauge. No such limitation was imposed upon the power of an electric locomotive, since it was connected with and could draw upon the boiler power in a central station. The practical consequence of this difference was that, during the starting period where large power was required for short intervals of time, the electric locomotive (or the electric multiple-unit train) answered to the demand without difficulty, while the steam locomotive reached the limit of its power at comparatively small accelerations. In the case of the London, Brighton, and South Coast Railway electrified service, for example, during the accelerating period the horsepower touched 1,600, a power quite beyond the capacity of any steam locomotive which could conveniently be employed on a suburban service. Once the journey speed had been attained, the steam locomotive had sufficient power to meet all the traffic requirements of local, express passenger, and ordinary and express goods services of the present time. The power of the motor to accelerate rapidly had secured its adoption, or at anyrate had largely influenced the electrification of steam services where the intervals between the trains were small and the stops frequent. The study of the characteristics of the motion of a train during the accelerating period had therefore assumed importance, an importance indicated by the fact that the actual choice of a method of traction for services of a suburban character depended upon the suitability of the tractor to work the train during the accelerating period.

The object of the paper was to explain a method by which time-speed, time-distance, speed-distance, and energy-distance curves might be derived from a curve of tractive force expressed as a function of the velocity, to consider a method of reducing the data obtained from a dynamometer-car record in order to obtain information regarding vehicle and engine resistance, to illustrate by means of a dynamical diagram the principles underlying the practice of braking, and incidentally to consider the question of the energy of rotation stored in the wheels of the train. The tractive force exerted on a train might be maintained at a nearly constant value by means of electric motors from the start up to the journey speed, and were it not for the fact that the train resistances increased with the speed the accelerating force would be constant and the dynamics of the problem would be simple. The tractive force exerted by a steam locomotive was a more variable function of the velocity during the starting period than was the case with an electric motor. From the start up to some ill-defined speed in the region of 50 revs. per minute, the tractive force exerted by a locomotive could be maintained at the approximately constant magnitude determined by the weight on the coupled wheels. The tractive force corresponding to the weight on the coupled wheels, exerted at 50 revs. per minute, roughly corresponded to a rate of working equal to the maximum power of the boiler. The power of the boiler varied somewhat with the speed, yet without serious error the power might be regarded as approximately constant above 50 revs. per minute, so that as the speed increased the cut-off must be reduced in order that the boiler pressure might be maintained. As the speed increased the steam found increasing difficulty in getting into and out of the cylinders through the pipes, ports, passages, and round the bends, the effect being to diminish the indicated horse-power which could be exerted at high speeds, since for a given cut-off and a fixed position of the regulator the weight of steam which found its way into the cylinder fell off almost according to a straight-line law as the speed increased. The curve of maximum tractive force for a steam locomotive was determined therefore, first, by the weight on the wheels; secondly, by the maximum boiler power; and, thirdly, at high speeds by the design of the ports, steam passages, and cylinders.

The author then explained the method of constituting a characteristic dynamical diagram for a particular case, the problem being to draw the time-velocity curve, the time-distance curve, the velocity-distance curve, the force-distance curve, and the energy-distance curve. The diagram brought out clearly how difficult it was to fix the limiting speed of a particular train. There would be no difficulty if the engine resistance and the vehicle resistance were known accurately, and if in addition the indicated horse-power developed in the cylinders of the locomotive could be predicted with accuracy. But these quantities were all difficult to determine, even with approximate accuracy, and each was subject to large accidental variations. Another point was the slowness with which the speed increased in the neighbourhood of the limiting speed. The diagram showed the necessity for engines with large powers of acceleration even for express services, so that the time required to attain the running speed might be reduced to a minimum. The same point was illustrated by the curve showing the velocity plotted on a distance-base.

DEVELOPMENT IN AUXILIARY UNITS BETWEEN EXHAUST PIPE AND BOILER.*

BY WILLIAM WEIR.

(*Continued from page 546.*)

INDEPENDENT AIR PUMPS.

FROM the statement of general principles, there is evidenced an early appreciation of the factors involved in the successful handling of the condenser air and water, but the actual development of a satisfactory apparatus shows a very slow rate of progress. To a certain extent this slow development was due to the very slight necessity for independent air pumps on account of the satisfactory performance of pumps driven from the levers—the size and speed being moderate.

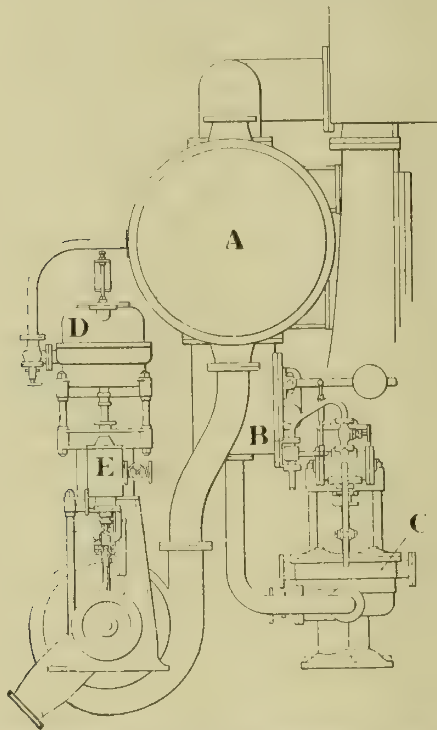


FIG. 5.—CONDENSING PLANT OF CABLE STEAMER "PACIFIC" (1903).
A Main condenser; B Condensed water pump control tank; C Condensed water pump; D Dry air pump; E Circulating pump engine.

The most obvious advantage of an independent air pump is its ability to obtain a vacuum in the condenser before the main engines are started, thereby enabling the engines to be manipulated with greater ease and certainty at times when immediate response is of importance. On this account, the first adoption of such pumps was on board war-vessels, and later for small river steamers, while the advent of the marine steam turbine made the provision of such pumps a practical necessity. At the present moment a considerable increase in the adoption of this auxiliary is taking place, even for reciprocating engine installations, on account of the ever-increasing powers of the vessels, and the necessarily increased risks with greater dimensions and higher engine speeds. The earliest designs of independent air pumps were those in which the pump was driven by an independent crank-shaft engine, and when the very variable and peculiar nature of an air pump load is considered, it will be obvious that a very meagre degree of success was possible, and that many failures resulted. Greater success was obtained when the air pump was coupled to the independent circulating engine, as these engines were under a considerable continuous load, and the variations of the air pump load were not so vital in their effect, but even this arrangement was frequently unsuccessful, particularly where lack of care was shown in the details of design.

The direct-acting independent air pump was originally developed in the United States, while in its details it was perfected in this country, and in the form of the "Twin" air pump thoroughly satisfactory results were obtained. A further degree of simplification in design was the advent of the "Monotype" pump, in which a single air barrel of the 3-valve type was driven by a single steam cylinder, and even now this constitutes a very successful type of pump for certain conditions. The suction-valveless pump, the features of which were originally enunciated in 1879, and which is now known as the Edwards air pump, offers distinct advantages as a type of air end for use as a lever-driven pump, but due to the principle of working, it is unsuitable for independent drive, and accordingly the old 3-valve air pump has still maintained its position as the most efficient air end for independent working.

When, however, the principle under which air and water should be withdrawn from a condenser is considered, it is obvious that the "Twin" or "Monotype" pumps require to be very large on account of their handling the air and water together. Where fitted of small dimensions, an undue degree of cooling of the feed water is necessary to enable them to obtain the desired vacuum, except under conditions of very slight air leakage. As already pointed out, it was early evident that the maximum efficiency would only be obtained by a combination of wet and dry pumps, and one of the earliest and most interesting marine examples was fitted to the cable steamer "Pacific" in 1903, while a similar arrangement was applied to a number of land and marine installations.

As will be seen from Fig. 5, the water from the condenser is removed by a float-controlled hot-well pump working entirely full of water, and automatically returning the condensate to the feed tank at the temperature due to the vacuum on account of its being subjected to contact with the entering steam. The air and vapour is handled by a suction-valveless dry air pump of small dimensions, driven at high speed by a prolongation of the piston rod of the circulating engine. The pump works at a low temperature imposed by a supply of injection water maintained at a low temperature by passage through a cooler. A modification of this arrangement is shown in Fig. 6, and represents the installation fitted to an early turbine cross-channel steamer, in 1903. In this example the water pump is uncontrolled, and handles a certain amount of air along with the water. The dry air pump is driven as before, by the circulating engine, and gives the necessary large air-pumping capacity. This arrangement also comprises one of the earliest examples of a properly-designed cooler circuit for a dry air pump.

A still further development of this nature is shown in Fig. 7, which was applied to a power station plant in 1902, and is chiefly interesting as representing one of the few actual examples of boiler feeding direct from the main condenser. In this connection it is interesting to note that as early as 1862 Messrs. Humphreys, Tennant, & Co. arranged on board the P. and O. Company's s.s. "Mooltan" an air pump which delivered the air and water up the centre of a hollow mast, from the top of which the air escaped while the static head of water fed the boilers directly.

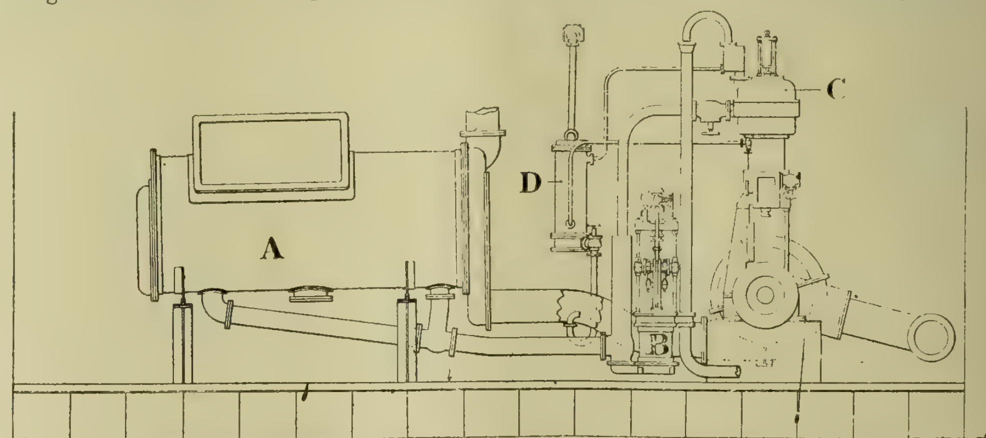


FIG. 6.—ARRANGEMENT OF CONDENSING PLANT ON S.S. "LONDONDERRY" (1903).
A Main Condenser; B Twin Beam-type Air and Water Pump; C Dry Air Pump; D Injection Water Cooler.

In the early stages of turbine propulsion many forms and

* Paper read before the Institution of Engineers and Shipbuilders, in Scotland, October 22nd, 1912.

combinations of wet and dry air pumps were fitted, but unfortunately these installations, in the majority of cases, were rendered apparently non-effective on account of faulty condenser design, and the present design of "Uniflux" condenser is a direct outcome of the apparent non-success of the inde-

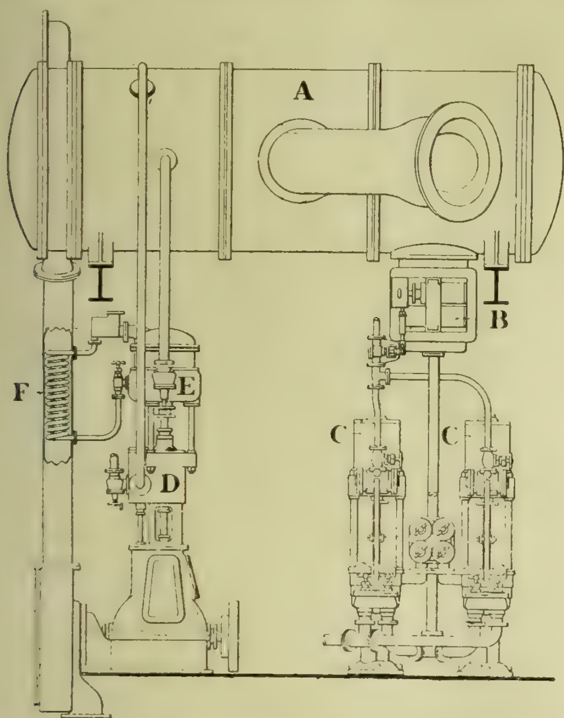


FIG. 7.—ARRANGEMENT OF CONDENSING PLANT AT BANBURY POWER STATION.

A Main condenser; B Float-control tank for main feed pumps; C Main feed pumps drawing from condenser and delivering to boilers; D Circulating-pump engine; E Dry air pump; F Injection water cooler.

pendent dry air pump. However, having succeeded in finding a satisfactory condenser design, the field was consequently clear for a fresh application of the wet and dry air pump principle. The main object was to secure a wet and dry pump in one unit, in order to obtain an apparatus of minimum weight, of greater simplicity and steam economy, together with greater reliability than had been possible with the separate wet and dry pumps. These advantages have been secured in the "Dual" air pump in a simple and compact form.

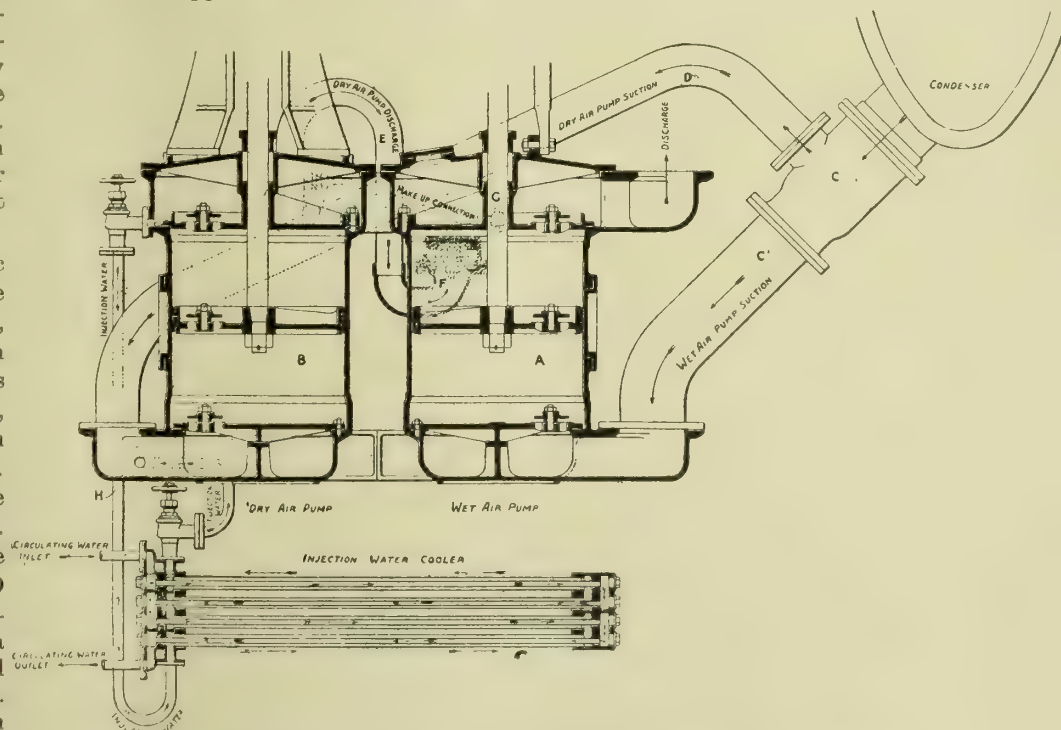


FIG. 8.—DIAGRAMMATIC SECTION OF WEIR "DUAL" AIR PUMP, COOLER, AND CONNECTIONS.

Fig. 8 shows, in diagrammatic form, the arrangement of surface condenser, "Dual" air pump, and injection water cooler. In all cases the wet pump A is situated below the steam cylinder, as this pump is the one which works under the maximum load. The dry pump B is driven by the beam and links in the usual way. One connection C is made to the condenser, but a branch pipe D is led to the dry pump, the connection being made in such a manner that the water will all pass by C' to the wet pump. Apart from the separate suction arrangements to each pump, the "Dual" pump differs from the ordinary twin pump in that the dry pump discharges through the return pipe E, through a spring-loaded valve F, into the wet pump, at a point below its head valves. This spring-loaded valve is adjusted to maintain about 8in. of mercury difference of pressure between the condenser, and what might be termed the hot-well of the dry pump.

The next point concerns the supply of water to the dry pump for water sealing, clearance filling, cooling, and vapour condensation. When starting the pump the filling valve G is opened for a short period, to enable the vacuum to draw in a supply from the hot-well of the wet pump. The valve is then closed and the water passes from the hot-well of the dry pump by the pipe H to an annular cooler through which a supply of sea water is circulated, and after being cooled the injection water passes into the suction of the dry pump, through the pump, and returns to the cooler in a continuous closed circuit; any excess caused by condensation passing over by the pipe E to the wet pump.

The advantages secured by such a combination are: (1) A wet air pump working approximately at the temperature due to the vacuum, in combination with a dry air pump working at a much lower temperature, on account of which it is enabled to handle air leakage without any substantial cooling of the main body of feed-water. (2) A dry air pump of high efficiency, due to its only requiring to discharge against 4lbs. pressure instead of 15lbs. as in the case of an ordinary air pump. (3) Reduction of load on beam, links, and levers, due to the light discharge load on the dry pump; this advantage being reflected in the reduced steam consumption. (4) A smaller and lighter air pump for equivalent duty, due to the high efficiency.

The "Dual" pump has also been adopted for working by levers from the main engines. This application is fitted on the s.s. "Rangatira" and a number of other vessels. These ships have twin screws with two sets of engines, each of 2,650 h.p. and the wet and dry air pumps are each 14in. diam., with a stroke of 20in., while the ordinary 3-valve air pump fitted for this power would be 24in. diam. by 26in. stroke.

When it is considered that the total load on the levers actuating the "Dual" pumps is 2,910lbs., and on the other 6,800lbs., the advantages are obvious, while the risk of accident so common to large engine-driven air pumps, due to sudden gluts of water, is very greatly reduced. The performance of these small pumps is shown on the air pump capacity table, and it is understood that no inconveniences have arisen with the small pumps when starting or manœuvring.

The factors involved in the estimation of the correct size of air pump to employ comprise in the first place considerations of the normal air leakage which the pump must deal with. This question is associated with the actual size of the installation. In a small installation the air leakage is always relatively higher than in a large one. It is further complicated by the nature of the installation, as it is obvious that in land

installations the opportunities of air leakage are few on account of the small number of joints on the vacuum system; correspondingly, in a marine dredger installation wherein the auxiliaries are numerous, and are all connected to the main condenser, innumerable opportunities for air leakage occur,

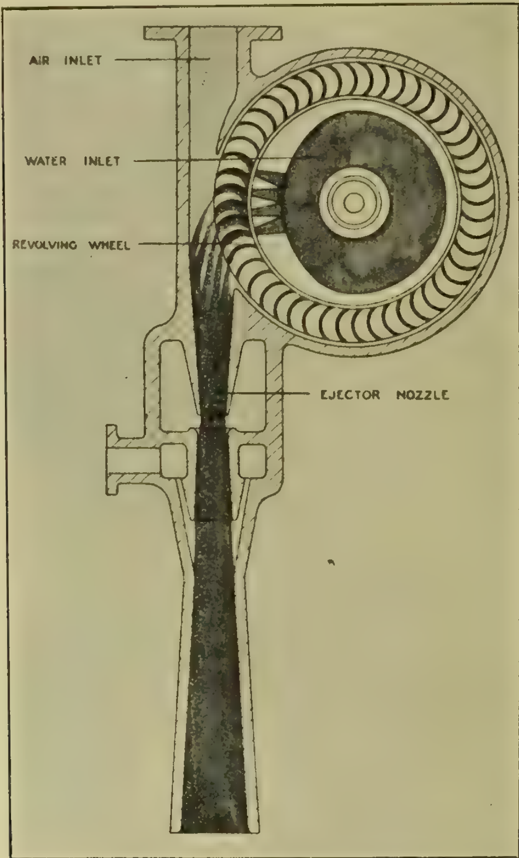


FIG. 9.—LEBLANC AIR PUMP.

and consequently the air pumps require to be of large dimensions. Further, in a torpedo-boat destroyer the permissible weight governs the situation as compared to a battle-ship.

These factors having been adjusted, the speed of the air pump requires consideration, and this necessarily involves the type of air pump. It also involves the actual size of the pump, as a small pump may run faster than a large one, and in addition, the wear and tear require consideration. Present practice results from the consideration of these factors, and experience enables their assessment to be made at the proper value.

TABLE III.

Comparative Capacities and Weights of Air Pumps.

Vessel.	Condensed steam per hour per pump.	Rate in lbs. per H.P. per hour.	Type of Air Pump.	Designed Vacuum. Inches.	Vol. swept by bucket / Vol. of feed water.	Lbs. weight of pump per H.P. of main engine.
S.S. "Kronprinz Wilhelm."	255,000	17	"Twin"	26	12·4	2·09
S.S. "Franconia"	90,000	15	"Dual"	26	7·4	1·102
Battle-ship (1902)	67,500	16	"Twin"	26	15·4	2·16
,, (1912)	94,500	14	"Dual"	28½	13·3	1·377
Turbine Atlantic Liner	196,000	14	,,	28½	13·2	1·232
Destroyer (1907)	124,000	16	"Monotype"	26	12·7	·765
,, (1912)	177,625	14½	"Dual"	28	8·8	·466
Small Turbo-Generator Set.	6,000	–	"Monotype"	28	33	—
Dredger Installation ..	15,000	—	,,	25	30	—
Three-throw Edwards type for electric power stations.	—	—	—	28½	45·50	—
Weir "Dual" air pump, for electric power station.	80,000	—	—	28½	20·5	—
S.S. "Campania"	40,000	—	Engine-driven ordinary	25	60	—
Cargo steamer	255,000	—	,,	25	45	—
S.S. "Rangatira"	40,000	—	Engine-driven "Dual"	25	26½	—

TABLE IV.—*Steam and Power Consumption of Independent "Dual" Air Pumps.*

Conditions.	Steam Consumption: percentage of feed water.
26in. vacuum for reciprocating engines	·65
28in. vacuum for turbine destroyers	·7 to ·8
28·5in. vacuum for turbine battle-ships and merchant vessels.	1·0
Electric-driven "Dual" air-pumps for electric power stations.	·16 per cent. of turbine output.
Electric-driven Edwards three-throw pumps for electric power stations.	·35 per cent. of turbine output.

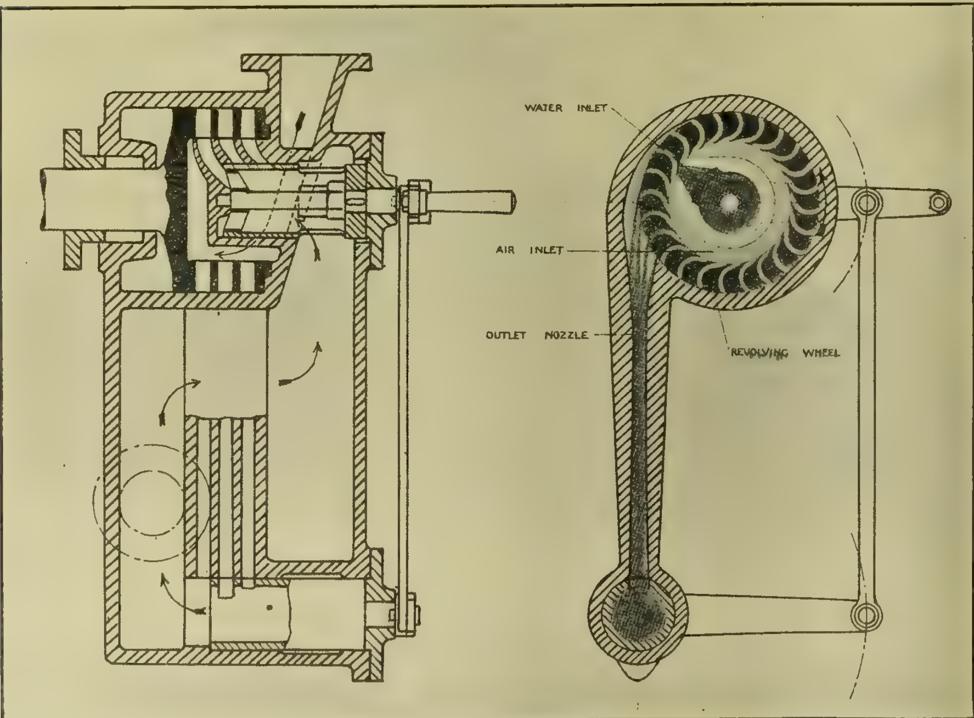


FIG. 10.—WEIR ROTARY AIR PUMP.

To enable the wide variation of practice in this respect to be seen, Table III. has been prepared, and gives the capacity in terms of air pump bucket volume swept to feed-water volume, also the weight of a number of air pump installations, from which it will be noticed that the present-day degrees of high vacua are obtained with less weight and capacity than the older arrangements of, say, 10 years ago. This arises in a certain degree from improved air pump design and also to the greater care taken to avoid air leakage.

It is of interest to note the large difference in capacity between the ordinary engine-driven air pump and the independent air pump, while the capacity usually provided for electric power station practice appears very excessive. Table IV. gives the average steam consumption of independent "Dual" air pumps for different conditions expressed as a percentage of the feed water they handle.

During the last few years much interest has been taken in

the development of rotary dry air pumps, especially for electrical station practice on the Continent; the two most notable examples are associated with M. Leblanc, of Paris, working in conjunction with the Westinghouse Company, and the rotary air pump constructed by the A.E.G. Company, of Berlin. While the utmost credit should be accorded to M. Leblanc for having developed the modern type of rotary air pump, it is of interest to note that in 1862, Christian Schiele, of Oldham, invented and built a rotary air pump regarding which he claimed: "The system or mode of expelling air from condensers by combining or entraining it with injection water on its passage through a fan or centrifugal pump."

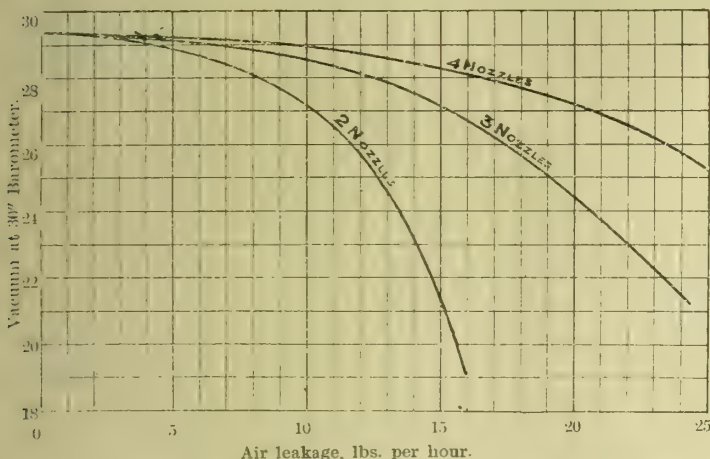


FIG. 11.—PERFORMANCE CURVES OF WEIR ROTARY AIR PUMP UNDER VARYING AIR LEAKAGES. INJECTION WATER TEMPERATURE 60° F.

Fig. 9 shows a section of a modern Leblanc air pump in which a single ejector and nozzle is used for discharging the air and injection water, the combination or admixture of the two taking place outside the turbine wheel. The A.E.G. design of rotary air pump is practically a Leblanc pump having a series of specially-shaped nozzles arranged circumferentially, the point where the air meets the entraining water being, as in the Leblanc pump, between the rotating wheel and the nozzles.

In a paper read before the Junior Institution of Engineers, in 1910, Mr. G. L. Kothny, speaking of the Leblanc pump, states that "the water is ejected into the collecting cone in the form of thin sheets forming absolutely tight water passages which entrap the air and non-condensable gases coming from the condenser, and carry them out against the atmospheric pressure." While useful as an explanation, this can hardly be accepted in a rigid sense, as it appears that the main desiderata in such pumps are to atomise or break up the water into practically a fog moving at a high velocity.

For marine use the adoption of rotary dry air pumps has been comparatively slow, due in a large measure to the very onerous and varied requirements to which a marine pump has to conform, and, further, to the extremely efficient nature of the existing direct-acting machinery. The necessity for driving such rotary machines by small steam turbines, in themselves, still more or less in the development stage, necessarily implies high steam consumption, while even the best rotary air pumps require the absorption of a considerable power per unit of air removed. Further, the existing types do not appear to possess any degree of flexibility, in the sense that being velocity machines they must always run at the designed speed and accordingly use the same amount of steam, thus causing their performances at low powers of the vessel to be fairly inefficient. Fig. 10 shows a recent development of the ordinary Schiele pump which has been designed with the object of imparting to it a certain degree of flexibility. It differs from the Leblanc and A.E.G. types in that the air is brought into contact with the injection water in the wheel itself somewhat similar to the Schiele pump—both passing through the wheel before being ejected through a simple nozzle; while in addition the wheel is constituted of four units, each being provided with a nozzle, and provision being made for closing any unit as desired, it enables the pump to run with whatever number of units are required to maintain the desired vacuum. Fig. 11 shows the performance, with varying air leakage, of a small pump of this design, with two, three, or four nozzles in use, the power varying practically in proportion to the number of nozzles, the amount absorbed by four nozzles being 9½ b.h.p.

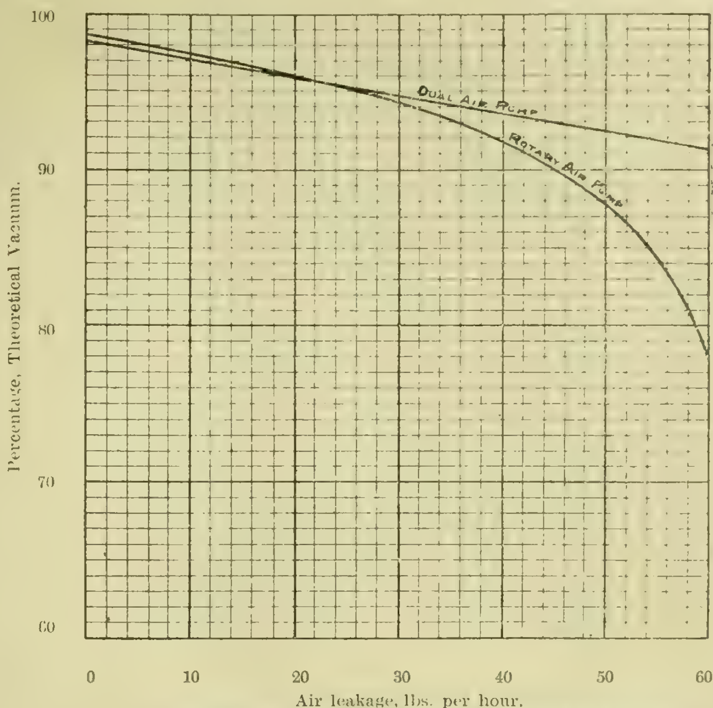


FIG. 12.—COMPARATIVE PERFORMANCE WITH VARYING AIR LEAKAGE OF "DUAL" AIR PUMP AND A ROTARY AIR PUMP UNDER SIMILAR TEMPERATURE CONDITIONS.

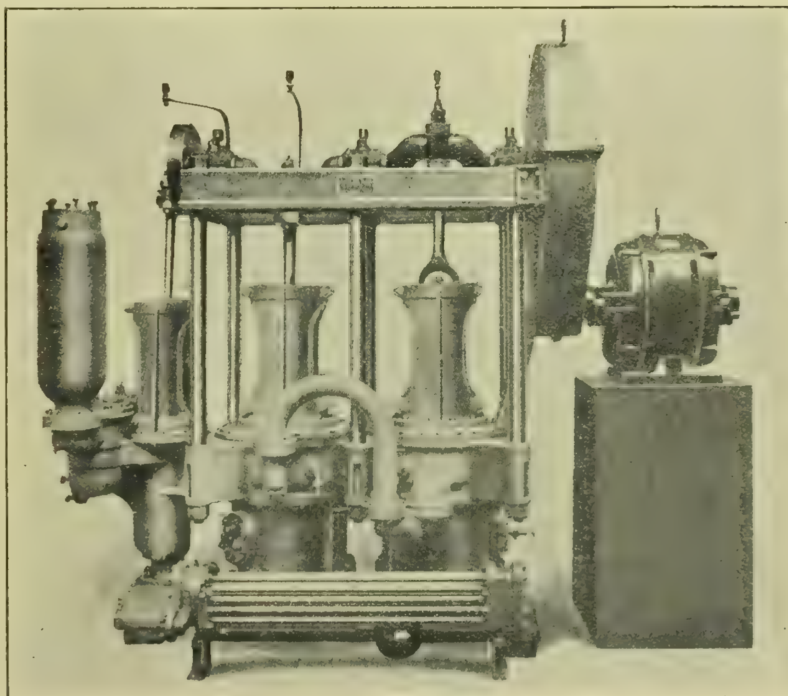


FIG. 13.—ELECTRIC-DRIVEN "DUAL" AIR PUMP.

While it is probable that the entrainment type of rotary air pump may be further developed, its ability to handle heavy air leakage only by the use of considerable power rather handicaps it for marine work at present. Fig. 12 gives a representation of the characteristic performance of a modern marine rotary air pump at varying air leakage, while on the same diagram there is shown the performance of a direct-acting pump. As regards the proportions of the two pumps, their weights are identical, provided no allowance is made for the cooler and tank necessary for the rotary air pump. The

relative steam consumptions of the two pumps, when doing the duty shown on the diagram, is as follows: —

Direct-acting pump .... 800lbs. per hour.
Turbine-driven rotary pump ..... 3,500lbs. per hour.

As will be seen from the diagram, the rotary pump maintains a very slightly higher vacuum than the direct-acting pump at small leakages, but rapidly falls off at large leakages. As already pointed out, a considerable adoption of rotary air pumps has taken place on the Continent for power station practice, but it may be suggested that even for this duty the latest development of direct-acting pump is worthy of consideration. Fig. 13 shows a special design of "Dual" pump electrically driven, supplied to the Yoker and Motherwell stations of the Clyde Valley Electrical Power Company. Each of the pumps handles the air and water from a "Uniflux" condenser fitted to a 5,000 kw. Westinghouse turbine, and when running at full load the motor driving the air and water pump absorbs 8 kw. or 16 per cent. of the total power. It will be obvious that the transmission of such a small amount of power ensures exceedingly slight wear and tear on the machine.

No review of condensing plant practice would be complete without reference to Sir Charles Parsons' vacuum augmenter, and it is another tribute to his inventive ability that he so early appreciated the great capacity of steam jets for handling highly-rarefied gases. The record of his research work in this direction, as outlined in his patent specifications bearing on the subject, shows the characteristic thoroughness with which he examined the possibilities of various methods of application.

The function for which the steam jet has proved most suitable is that of creating a slight pressure difference at a very low absolute pressure, and it is thus applied in the vacuum augmenter for banking up the non-condensable gases from the condenser into the air pump suction. The necessity for condensing the steam admitted to the system in the steam jet was met by the provision of a separate small surface condenser. Attempts have been made to replace the augmenter condenser by an apparatus of the jet or direct-contact type, using the feed-water as a condensing medium, but for this purpose, as for the main condenser, the surface type has been, and will probably remain, most generally suitable.

(To be continued.)

ELECTRICITY IN MINING.

At the opening meeting of the Newcastle Local Section of the Institution of Electrical Engineers, the chairman, Mr. W. C. Mountain, in his inaugural address, said he felt gratified, on looking back, to see that his early views regarding the possible applications of electricity to mining machinery were now an established success, and it was undoubtedly the case that electricity was now essential for the economical working of any modern colliery or mine. Where electricity could be supplied at a price within measurable distance of that at which it could be generated at the colliery, coalowners were, he considered, well advised to take such a supply, and to expend their capital in the increased application of electricity for winding, &c., instead. It had to be remembered, however, that there was usually a large amount of unsaleable coal, good enough for steam-raising purposes available, and they had also waste heat from coke ovens, &c., which could be utilised.

Gas engines of 3,000 h.p. to 4,000 h.p. were at the present time in use and giving every satisfaction. At normal load a large engine would take about 10,000 B.Th.U. per horse-power hour, and as the average heat value of blastfurnace gas was about 100 B.Th.U. per cubic foot, the consumption per brake horse-power per hour would be about 100 cub. ft. Owing to the higher heat value of coke-oven gas the corresponding figure with it was about 22½ cub. ft. From the gas engine exhaust, from 2lbs. to 2½lbs. of steam per hour per brake horse-power, at 60lbs. pressure, could be generated regularly, and this could be utilised in many ways. On an average, the gas evolved per ton of pig iron smelted was about 160,000 cub. ft. About one-third of this would be used in the ovens, one-eighth by the blowing engines (if gas driven), and about one-tenth would be lost, leaving about 45 per cent. available, say, 72,000 cub. ft. In large gas engines this would give 30 h.p. per ton melted, in 24 hours. With coke ovens the production of gas was about 10,000 cub. ft. of gas per ton of coal coked, and half of this would be surplus, with regenerative ovens. Roughly speaking, from 1lb. to 1½lbs. of steam could be generated per pound of coal coked. The author quoted some figures taken from plants he had recently reported upon or installed. In one exhaust steam plant, after allowing for interest and depreciation, attendance, repairs, upkeep, and, in some cases, a certain amount of coal for producing steam when exhaust steam was not available, the cost had been as low as 0·15d. per unit, and in other cases only 0·2d. per unit, notwithstanding a load factor of only 30 per cent. He had on previous occasions shown that, on an equal basis, electric winding was possible with coal at 8s. to 10s. per ton, where coalowners had to install their own generating plant; and even now, although the price of electrical plant was less, he still thought that for the heaviest work the modern steam winder could more than hold its own. But for small outputs there was a very large field for electric winding, and a very considerable amount of work was being done in this direction. The use of helical-cut gearing had assisted greatly, as it enabled smaller and cheaper motors to be used. The simple induction motor was quite suitable in cases where the peak load when starting did not cause any trouble. The use of a motor generator introduced risk of breakdown. For cables in mining work he preferred those insulated with bitumen, provided there was no risk of decentralisation of the conductors. The pillar type of switchgear, with draw-out arrangements for isolation, was very satisfactory for use underground. Care must be given to the earth connection of the armouring of the cables to switch cases, as well as to the junction boxes, controller cases, and motor frames. The slip-rings of motors should be enclosed if there was any likelihood of gas being present, but he did not consider the total enclosure of large motors satisfactory. Broadly speaking, total enclosure was a mechanical protection only, as doors or covers might be left improperly secured; and where there was any positive danger of gas in part of a colliery, it was better to install compressed air there. Electrical compressors could be employed near these places, but the average disc coal cutter consumed about 600 cub. ft. of free air per minute at 45lbs.-50lbs. per square inch, and each such machine would, therefore, require 70 h.p. to 75 h.p. in the motor compressor, the resulting efficiency being 30 to 40 per cent. compared with the direct use of electricity. Taking the horse-power at £5 per annum, this meant an additional annual expenditure of about £250 per coal-cutter. Three-phase coal-cutter motors might be wound for as low a pressure as 110 volts, which could not cause a dangerous shock, a small transformer being combined with the gate-end switch. High-pressure current could then be brought by small cables near the working face, and possibly the total cost would be lower than if the standard voltage of 500 volts were adopted.

For high lifts the 3-throw plunger pump was better than the centrifugal pump, in point of efficiency, the combined efficiency often being as high as 80 per cent. Single-reduction helical gear had improved the efficiency, but it ought always to run in oil. For large volumes of water at moderate heads, the centrifugal pump was better. Portable pumps should be of 3-throw type. Electric haulage had made enormous strides, its economy being unapproachable. Some years ago, Mr. Mountain substituted an electric for a compressed air haulage, with the result that the engine indicated horse-power was reduced from 500 to 166.

New British Submarine.—There was launched from the yard of Messrs. Vickers, Ltd., on the 29th ult., the submarine E3, built for the British Admiralty. The new vessel is one of 13 of the E class building at Barrow, and she is designed on lines to be of service in engagements well out at sea. She is driven by heavy oil engines.

Internal-combustion Locomotive. — An internal-combustion locomotive is being built for test on the Reading railroad, and will contain a 550 h.p., 6-cylinder gasoline engine, suitable for either high-grade or low-ignition fuel oil. It is claimed that this locomotive will be capable of negotiating grades and carrying loads as great as a small steam locomotive, and that the direct drive of the steam locomotive has been adapted to the internal-combustion engine.

SULZER'S CALORIMETER FOR FLUIDS.

THE calorimeter shown in the accompanying illustrations, the invention of Sulzer Bros., Winterthur, has been designed for measuring and indicating the quantity of heat of a flowing liquid or gas, and is capable of being utilised for indicating in hot-water heating installations the quantity of heat given off thereby, or by individual sections thereof. The device, which contains an expanding body, is so constructed that it gives the product of the quantity of fluid passing through it and of the temperature of the fluid, and thus indicates directly the quantity of heat without necessitating any calculation for the purpose. Two constructions

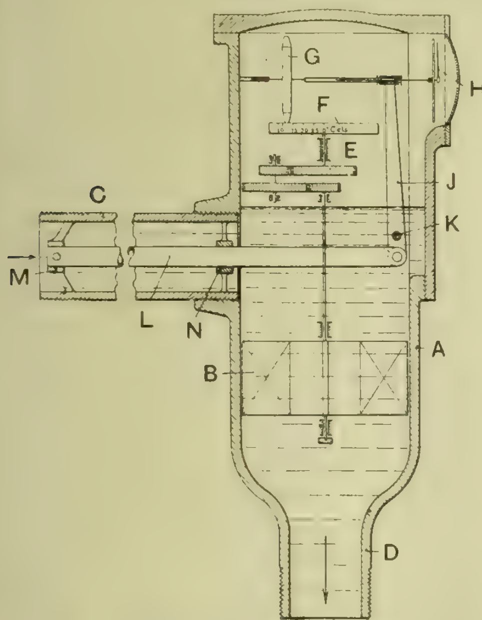


FIG. 1.—SULZER'S CALORIMETER FOR FLUIDS.

are illustrated, Fig. 1 being a vertical section through a device which indicates the quantity of heat of a passing liquid, and Fig. 2 a similar view of a device by means of which it is possible to determine the quantity of heat given off by a particular branch or section of a heating installation.

In the construction shown in Fig. 1, the casing A contains a liquid measuring device B through which flows the medium whose quantity of heat is to be measured on its way from the flow or supply branch C to the return pipe D. The rotation of the water-measuring wheel is transmitted by means of a toothed wheel or worm gear E, which reduces its speed to the disc F. This disc in its turn engages a friction wheel G, whereby its motion is transmitted to an indicating mechanism H. The friction wheel G can be shifted on the disc F by means of a lever J pivoted at K to the casing, and connected to the lever is a rod L secured in the branch C at M and passing through a guide N. The rod L expands with the increase in temperature of the heating medium passing through the device, and contracts when the temperature thereof falls. In that way, when the temperature rises the friction wheel G is shifted by the lever J over the disc F away from the axis of the latter, whereas when there is a decrease in temperature the friction wheel is brought nearer to the axis. Assuming the number of revolutions of the liquid-measuring device to remain constant the friction wheel G, and consequently the indicating mechanism H, will therefore be driven at a greater speed by the disc G when the temperature increases than when the temperature sinks. As the speed of the disc G depends on the quantity of water passing through, the pointer H will accordingly indicate directly the quantity of heat corresponding to the product of the quantity of water and the temperature of the water.

If the heat-measuring device above described is to be used for ascertaining the quantity of heat consumed in a given section of a hot-water heating installation, one device of the kind described is inserted into the hot-water supply pipe and a second device of the same kind is arranged in the return or discharge pipe of the heating section in question, and the quantity of heat consumed is ascertained by comparing the heat contained in the water supplied with the heat still remaining in the water discharged. The two devices may in that case be combined in one, controlled partly by the water supplied and partly by the water discharged, and indicating directly the difference in the quantities of heat. A device of the latter kind is illustrated in Fig. 2. The arrangement is, on the whole, similar to that shown in Fig. 1, only the lever J is controlled by two heat expansion bars L, L_1, one of which L is arranged in the supply pipe C and the other one L_1 in the return pipe C_1. The expansion bar L is pivoted to the lever J at R, whilst the bar L_1 is pivoted to the lever at S.

If, assuming the same quantity of water is passing through, there is an increase in the temperature difference between the water in the supply pipe C and in the return pipe C_1, the bar L will expand more than the bar L_1, or it will contract less than the bar L_1 or it will expand whilst the bar L_1 will contract. In any case, the pivot point R will in consequence be shifted to the right relatively to the pivot point S, the extent of its movement being proportional to the difference in temperature between the liquids in the pipes C and C_1. In that way the friction wheel G will be moved away from the axis of the disc F and transmit the motion of the gear E to the indicator H with greater speed than before.

In the case of a decrease in the difference in temperatures between the contents of the pipes C and C_1 the reverse will take place. The indicating mechanism will therefore show not only the quantity of water passing through, but also the quantity of heat (corresponding to the product of the said quantity of water and of the difference in the tempera-

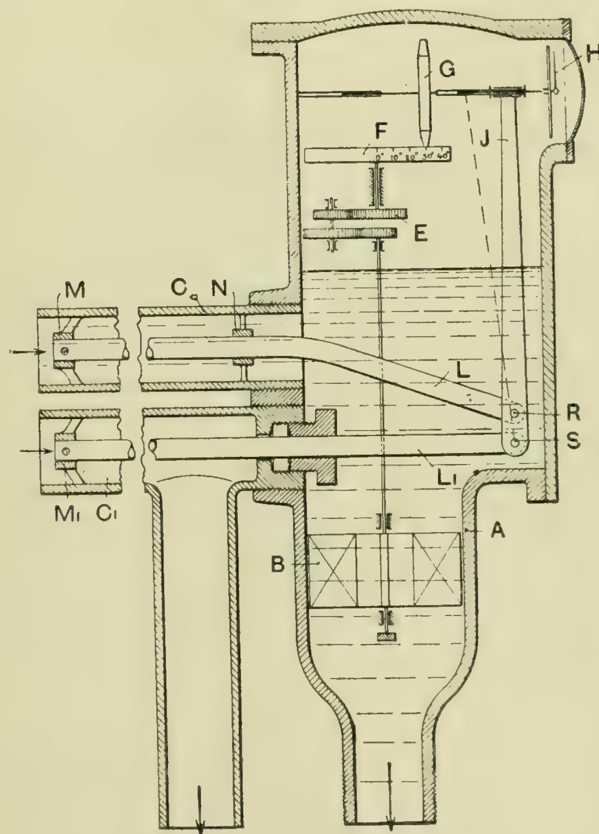


FIG. 2.—SULZER'S CALORIMETER FOR FLUIDS.

tures of C and C_1) consumed in the particular section of the heating installation. Should the temperature in C and C_1 increase and decrease to the same extent, and in that way the difference in temperatures remains the same, the bars L and L_1 will expand or contract uniformly and in the same direction, so that the pivot points R and S will be jointly shifted to the right or to the left. There will then take place a parallel shifting of the lever J, which, however, will be so slight owing to the small difference in length of the heat expansion bars that the shifting of the friction wheel G produced thereby will be of no practical importance. When, however, the pivot points R and S are shifted unequally the friction wheel G will be appreciably moved owing to the magnifying effect of the lever J.

METROLOGY IN RELATION TO INDUSTRIAL PROGRESS.*

BY SAMUEL W. STRATTON, D.ENG., D.SC.,
DIRECTOR OF THE U.S. BUREAU OF STANDARDS.

BEFORE the development of modern science, metrology included only the simple weights and measures necessary in commerce and trade. The adoption and preservation of standards of weight and measure, the means of making them accessible to the public, and the enactment and administration of laws preventing the use of incorrect weights and measures have been questions of vital interest to every nation from the beginning of history.

Naturally, the early standards had their origin in some object in Nature, thus recognising the most vital principle of modern metrology, namely, reproductibility. A history of these standards would prove most interesting. Each community had its own standards, but as trade grew, due largely to the improvement in transportation facilities, it became necessary to unify the standards of communities doing business with each other. During the past century every commercial nation has been compelled to put its standards on a national basis. The time is not far distant when the same force which compelled the various sections of each country to adopt uniform national standards will bring about international uniformity. The countries of the world are closer together to-day, commercially, than were the sections of each country 100 years ago.

The developments of modern science necessitated the introduction of a new factor in metrology, namely, precision, since precise measurements form the foundation of practically all scientific investigation. Commercial standards were not sufficiently reliable or accurate for scientific purposes. The progress of science demanded correctly-defined units and accurate material standards for each physical quantity to be measured, whether in the field of mechanics, heat, light, or electricity. Practically all of these units and standards are based upon the fundamental units of length, mass, and time, and involve measurements of these three fundamental quantities of the utmost refinement in order that the derived units may be determined with the order of accuracy required even in the industries. Hence, much scientific effort has been expended upon the improvement of the units and standards of these fundamental quantities, and the derived units and standards form a never-ending field of scientific research.

But the field of metrology does not end with the fixing of the fundamental standards of length, mass, and time, and the derived units in the field of mechanics, such as force and energy and power, or the deriving and fixing of the various standards used in measurements of heat, light, and electricity, but it includes the determination of a large number of values known as physical constants, such as the mechanical equivalent of heat, the boiling points of liquids, the melting points of solids, thermal and electrical conductivities, the optical and radiation constants, and many others. Accurate values of these constants are as necessary as correctly-defined units or accurate standards of measurement. They enter into practically all scientific work, whether pure or applied, and may be termed "standard values."

Again, the field of metrology is rapidly being extended to include standards of quality. It is often desirable, especially in the industries, to define the quality of a material in terms of its physical and chemical properties, to specify, as it were, its standard of quality. As metrology forms the basis of investigation in the field of natural science, so do the natural sciences constitute the principal factor in industrial progress. When Germany determined to take a leading part in the industrial world, she began by encouraging scientific investigation and instruction. She had reached the front rank in the scientific world long before reaching that same position in the industrial field, and her phenomenal industrial progress can be attributed to the application of scientific methods and principles more than to all other factors combined.

Metrology has a direct bearing of great importance upon industrial progress, as shown in the interchangeable method of manufacturing, a method depending upon the accurate measurement of length, the accurate measurement of temperature in the steel, glass, ceramic, and other industries where it was formerly estimated, and no field of industry owes more to metrology than that of applied electricity. These are but a few of the vast number of cases that might be recited, but metrology is probably far more important to industrial progress, indirectly through the channels of applied science.

The United States has enjoyed a remarkable period of industrial prosperity, due to the enormous home consumption of their manufactured products by a rapidly-increasing population of a new and growing country, and the retention of the home market for their own use. Nevertheless, competition as to quality is growing very keen, and manufacturers are becoming aware of the great importance of scientific investigation, the leading industries are rapidly establishing research laboratories in which units and standards of measurements are the principal means of attacking the difficult problems they are called upon to solve. These laboratories are quite as exacting in their requirements as to accuracy as the laboratories of scientific institutions. The usefulness and efficiency of such laboratories are increased many-fold by the access to accurate, reliable standards and methods of measurement. There is scarcely a business transaction, an exchange of commodities, an article manufactured, or a structure erected that does not refer in some way, either directly or indirectly, to standards of measurement.

Every progressive country has recognised early in its history that the fixing of standards is a governmental function and has early made provision for the maintenance and use of the standards used in trade. Later, these countries, recognising the new and broader field of metrology and its vital relation to industrial development, have established national institutions equipped for scientific investigations in all branches of metrology. The first of these was the Physikalisch-Technische Reichsanstalt, established by Germany in 1884, dealing with the newer branches of metrology, including light, heat, electricity, and the determination of important physical constants in these same fields of science. This institution was, in addition to the laboratory of the Normal Eichungs-Kommission, having to do only with the ordinary standards of trade, and its phenomenal influence upon the industrial development of Germany is too well known to comment upon at length at this time. Later there was established in Germany still another institution, the Material Prüfungsamt, dealing with the subject of metrology in its newest and broadest sense, namely, the determination of the properties of the more important materials of construction and other industrial products. While this latest standardising institution is essentially supported by the Prussian Government, its influence is felt throughout the Empire.

In 1898, Great Britain established the National Physical Laboratory near London, again an institution made necessary by the ever-widening field of metrology. This institution is growing by leaps and bounds and is already an important factor in the industrial development of that country. It has taken a place in the front rank of scientific laboratories and is doing a great work. In the United States the founders of the Government gave to Congress the responsibility of fixing the standard of weights and measures by constitutional provision. In framing this paragraph of the Constitution, they no doubt had in mind as examples the standards then recognised as necessary; but the principle involved and established applies equally well to the standards of electricity, heat, and all others that have become necessary, or may become necessary in the future, to commerce, trade, and industry.

In 1872, a conference was held in Paris by the representatives of 30 countries, and provision was made for the construction of new metric standards of length and mass. They were made of an alloy of platinum and iridium, the most durable materials known, and by the most accurate methods known to science at the time. The copies sent to the United States in 1890 were adopted by the Secretary of the Treasury as our metric standards. In 1893, the relations between the yard and the metre and the avoirdupois pound and kilogram were fixed by that official, based, of course, upon an accurate comparison between the standards of the two systems. From this time the metre and the kilogram became the fundamental standards for both systems, thus giving to the common system the advantages of the metric, so far as permanency and accuracy are concerned. One should not confuse the terms "unit" and "standard"; if the relation between the yard and metre—both units—is known, then it is only necessary to measure off on a subdivided metre that portion which has been

* Abstract of paper read before the Franklin Institute.

defined as equivalent to the yard. In a similar manner, the pound is determined from the standard kilogram.

A few examples of the work now in progress at the United States Bureau of Standards will perhaps illustrate better than by any other method the relation of metrology to the industries. Those familiar with manufacturing need scarcely be told the importance of length, mass, volume, and density measurement in all branches of industry. The requests for the comparison of length standards come from the makers of all kinds of length-measuring instruments, from the makers of machinery and tools. Practically all of the measuring tools of every sort used by workmen in construction are made from standards that have been compared with those of the bureau. The bureau is never without the standards of the makers of weights; the standard weights of manufacturing concerns, railroad companies, or the precision weights used in industrial laboratories, all awaiting comparison with the Government standards. Oil companies have their standards of capacity verified. Gas meters are referred to standards of capacity—as well as the glass measuring apparatus used in industrial and scientific laboratories. Hydrometers, or instruments for measuring the densities of liquids, are used in great quantities and variety; tables of densities of various kinds must be prepared for use in connection with them. These are but a few of the instances involving standards of length, mass, capacity, and density, to which one of the largest sections of the bureau is devoted.

The electrical industries are as exacting as to their requirements of standards as scientific laboratories. This industry has, perhaps, more than any other, adopted scientific methods and precision measurements. The standards of the makers of electrical measuring instruments, as well as those of the producers and users of electrical energy, must be compared with a common standard, and that standard (or standards, as there are several of them) must be derived from the fundamental standards of length, mass, and time—an exceedingly difficult operation. The Electrical Division of the bureau was called upon recently by the electrical industries for a determination of the conductivity of copper—a physical constant of great importance to that industry—and it is frequently called upon to determine the electrical properties of materials. It is undertaking an investigation of the electrolysis effects of stray currents upon underground pipes or other metal construction with a view of determining some of the data necessary in standardising electrical construction and the prevention of electrolysis, an excellent illustration of the many investigations in progress at the bureau for the determination of the properties of materials under specific conditions, in order that they may be more properly used.

In addition to the vast number of temperature measurements made at ordinary ranges in industrial processes, many of these processes depend for their success upon measurements of high temperature. This is especially true of the steel, glass, porcelain, and similar industries. No branch of metrology presents more varied problems or is more closely connected with industrial progress. The calorific values of gases and other substances are being determined. Only a few days ago the refrigerating industries requested the bureau to determine the heat constants of ammonia and brine, the heat-insulating properties of materials, and other constants needed by that important industry. Many of the constants and values given in tables of reference are out of date and need to be redetermined with all the precision possible in modern metrology.

One scarcely thinks of optical measurements in connection with metrology or industrial progress, and yet optical measurements are an important factor in both. The applications of spectrum analysis are many. The duty upon imported sugars is collected according to the amount of pure sugar they contain, as determined by measurements involving the principles of polarised light, and everyone is familiar with the relation of photometry to the gas and electric industries. Standards of colour and colour-measuring instruments are desired that are applicable for the measurement of the colour of textiles, paper, pottery, and many other materials. In fact, an instrument for measuring colour has been recently developed at the bureau, and the substances mentioned are those that were being measured but a few days ago during my visit to this particular laboratory. Investigations are in progress for the purpose of determining the data necessary in defining the optical properties of the various lens combinations, such as field glasses, photographic lenses, telescopic objectives and others, and also the means of specifying and measuring these properties.

Metrology, in the broad sense, includes not only the various fields of physics, but chemistry as well. Scarcely a problem is taken up, either in connection with standards of measurement, constants, or the properties of materials, that does not involve chemical analysis. Standard irons, steels, ores, and so forth, of known compositions are required by the metallurgical industries; the chemical industries are demanding standards of purity in reagents.

Standards of quality have to do with the manufactured product rather than the process of manufacture, and they have an exceedingly important bearing upon industrial products. The newest and largest section of the Bureau of Standards is that devoted to the investigation and determination of the properties of the more important structural and engineering materials in order that they may be correctly specified and most efficiently used. The bureau tests large quantities of such materials purchased by the Government. In doing this, it is brought in contact with faulty definitions, imperfect specifications, and, in many cases, the entire absence of standards of quality or suitable methods of testing. This work is of great financial value to the Government, but it is insignificant as compared with that of the knowledge that is gained by doing it and which can be given to the public.

The bureau endeavours to serve as a clearing-house for knowledge pertaining to metrology. Scarcely a day passes that it is not visited by several representatives of various industries seeking information as to standards, methods of measurement, or the properties of materials; every mail brings scorces of such enquiries from every section of the country and from all branches of industry. The bureau serves as referee in many cases of dispute when questions of standards are involved, and it is frequently instrumental in bringing about an agreement between manufacturers and users as to standard specifications.

There is a decided and rapidly-growing tendency on the part of the public to purchase structural and other materials according to properly-framed specifications, and to ascertain, by suitable tests, whether or not the articles purchased comply with the specifications. Hence, the bureau encourages the establishment of local testing laboratories, especially in the large cities, by furnishing them with standards, assisting them in the preparation of specifications, and giving them the results of much valuable experience gained in doing similar work for the Government. The time is not far distant when every large city will have its testing plant, dealing not only with the measurements involved in the public utilities, but testing all materials purchased for use in public work.

Finally, I would call attention to the efforts of the bureau toward promoting international agreement as to the fundamental questions involved in metrology. Largely through its influence a very close co-operation has sprung up between the various national bureaus. They are continually exchanging standards and comparing methods. The necessity for international agreement in such matters is becoming daily more and more apparent. The scientific world employs only international standards — why should not the industrial and commercial world enjoy the same privilege?

Future of the U.S. Petroleum Industry.—According to the "Fuel Oil Journal," the future oil supply of the United States will be derived from the distillation of oil saturated shale, which is to be found in half the States of the Union, as the supply from wells will not be equal to the demand, even when new oil fields are developed. If the consumption of petroleum increases at its present rate, 290,000,000 barrels will be needed to meet the demand in 1917, a demand which can only be met by the distillation of shale oils to supplement the supply from wells. As evidence of the statement that the demand is outstripping the supply, it is pointed out that Pennsylvania crude oils, which sold at 6s. 5d. per barrel at the wells last December, are now offered at from 6s. 8d. to 7s. 2d., and similar advances have taken place in all other oil-fields. The present reserve stocks of "light crudes" in the United States are estimated at 80,000,000 barrels, as against 95,000,000 barrels in July, 1911, as a result of refiners having been compelled to draw on their reserves, and the impression is strong in the oil industry that new fields of sufficient size to stop this drain on reserves will not be found.

INTERNATIONAL ENGINEERING AND MACHINERY EXHIBITION, OLYMPIA.—V.

Mr. John Thompson, of Wolverhampton, exhibited a section of a Lancashire boiler having "Thompson" dished ends and corrugated flues. This boiler, it is claimed, possesses advantages over the flat-ended type in that there are no stays, thus making it easier to clean, and there are no stay rivets to leak (some 500 of these being entirely dispensed with). The positions for the feed valves and steam gauges are also pressed from the solid plate, and thus all rivets are removed from the ends, except those connecting shell and flues. The corrugated flues also give increased heating surface, as well as greater freedom for expansion and contraction.

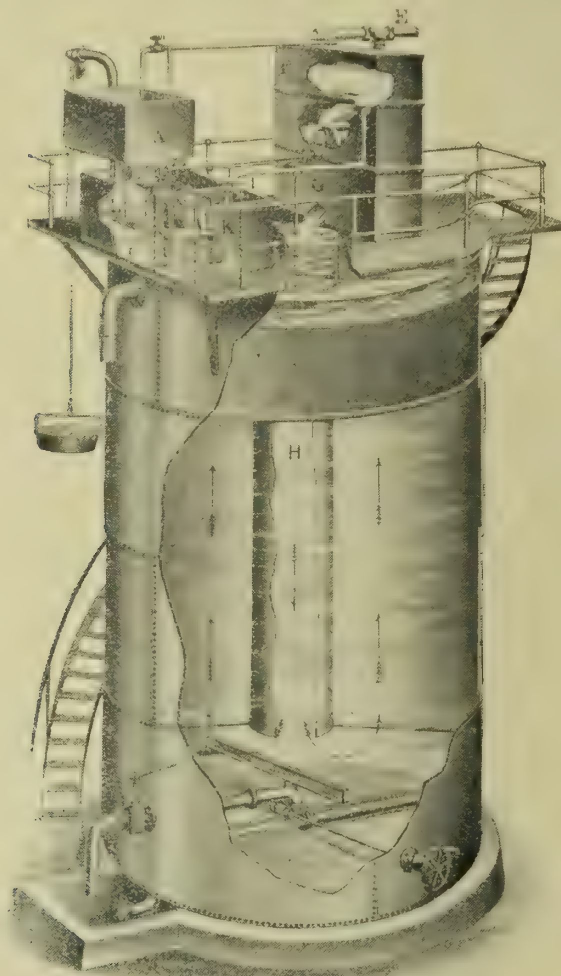


FIG. 1.—KENNICOTT WATER SOFTENER. MR. JOHN THOMPSON, WOLVERHAMPTON.

Fitted to this boiler section was a "Thompson" forced draught furnace, enabling inferior fuels to be used, the high rate of combustion compensating for the lower evaporative value of these fuels; while at the back of the boiler was shown a "Thompson Mars" bent-tube superheater, having 30 tubes, and 200 sq. ft. of heating surface, and a "Thompson Mars" economiser having 96 tubes, and 960 sq. ft. of heating surface. A "Kennicott" water softener was also shown at work on this stand, and as it possesses several interesting features we illustrate it and describe its action herewith (see Fig. 1). Referring to this illustration, A is a lime-slaking tank into which a calculated quantity of lime is put, and slaked with sufficient water to make it thin enough to flow. Then the lime is allowed to flow through a valve into the chemical tank B. A calculated quantity of soda is put into the chemical tank B with the slaked lime, and enough water added to fill it to a definite point. The agitator C propelled by the water wheel D keeps the contents of the chemical tank thoroughly mixed.

The water to be treated enters by way of the hard water inlet pipe E into the hard water box F, where it is divided. The greater part of the water flows through an opening in the bottom of this hard water box, over the water wheel D, and through a chute G into the top of the "down-take" H. The lesser part flows through a pipe into the dividing box I, where it is divided by a proportioning slide J, one part flowing into the regulating tank K, and the other part into the top of the "down-take" H through a pipe. The proportioning slide J may be set according to graduations on the side of the dividing box I, so that the regulating tank K will fill in a definite number of hours, the machine running at full capacity.

The head of the lift pipe L in the chemical tank B is connected by a chain to a float M in the regulating tank K. As the regulating tank K very slowly fills with water from the dividing box I, the float M rises, the head of the lift pipe L lowers, and the contents of the chemical tank B flow out through the lift pipe into the top of the "down-take" H, where they are thoroughly agitated with the water to be treated, which comes in over the water wheel.

The method of sedimentation is then as follows: The purifying materials and the water to be purified, which enter the "down-take" H, as described in the foregoing paragraph, are intimately mixed by the agitator, so that precipitation of the scale-forming matter at once takes place. The water, together with the precipitated lime and magnesia, travels slowly downward through the "down-take" H, and the precipitate falls away from the water in the main settling tank, whence it is, at regular intervals, removed by means of revolving sludge pipes. The few remaining particles of precipitate, if any, have another opportunity to settle, as the water, after passing downward through the "down-take" H,

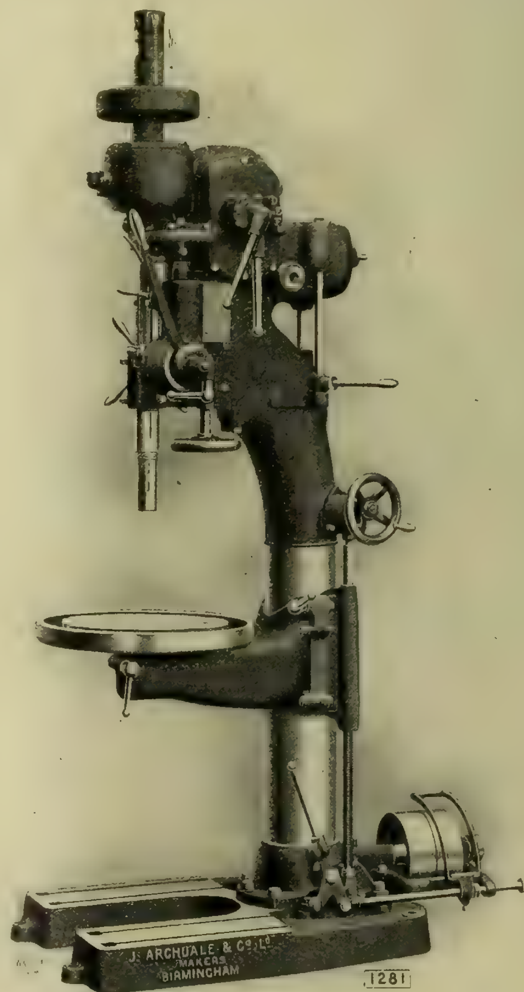


FIG. 2.—HIGH-SPEED VERTICAL DRILLING MACHINE. MESSRS. JAMES ARCHDALE & CO., LTD., BIRMINGHAM.

turns and passes up in the space between the "down-take" and the shell of the main tank. As a final purification, the rising water moving at its lowest rate passes through a wood fibre filter near the top of the apparatus (shown in the illustration just below the mouth of the "down-take" H),

whence it emerges soft, clear, and ready for use. As the main tank always stands full of water, the clear, soft, treated water discharges from the overflow on the side of the main tank at a point above the filter as fast as the water to be treated enters the top of the "down-take." When the regulating tank K becomes full, it is emptied, another charge of lime and soda is put into the chemical tank, and as the regulating tank again very slowly fills, the charge of lime and soda flows out through the lift pipe.

It will be seen, therefore, that the machine is continuous and wholly automatic in its operation, the flow of water furnishing all the power necessary for mixing the chemical reagents with the water and for operating the mechanism.

Messrs. James Archdale & Co., Ltd., of Ledsam Street, Birmingham, a firm well known to our readers, had a large and interesting exhibit of machine tools in the centre of the building. Amongst these we may mention a 3ft. 6in. ball-bearing sensitive radial drilling machine of the all-gear type, drilling up to 1½in. diam. in steel; a 3ft. 6in. all-gear radial machine drilling up to 2½in. diam. in steel, and having 18 spindle speeds instantly changed; a 32in. vertical drilling machine of the all-gear type, having two ratios of gearing changed by lever, instant reverse to spindle by lever and friction clutches, eight spindle speeds, and four rates of gear-driven feeds; a 7in. capstan lathe, having all-gear headstock, bar feed admitting 1¾in. diam., self-acting, sliding, and screw-cutting motions to saddle, reversing gear for cutting right and left-handed threads, hexagonal capstan with self-acting motion and self-selecting stops, gear feed motion, &c.; a horizontal milling machine of the all-gear type, having as a special feature the table arranged for rapid manipulation, and fitted with a patent device for starting the gear feed motion, no time being thus lost in idle movement of feed, whilst damage to cutters is prevented; a 28in. vertical drilling machine; a 3ft. sensitive radial drilling machine; and a 9in. capstan lathe. The three latter machines we have pleasure in illustrating and in describing at length below.

Fig. 2 shows the 28in. vertical drill, a rigid and powerful machine of the all-gear type. The spindle is driven through a 9-speed gear box of the sliding wheel type, self-contained in the top frame, with change levers in convenient positions. It can be stopped, started, reversed, and speed changed by levers within easy reach of operator, and all gears for speed change, reverse, and spindle drive run in an oil bath. The positive gear-driven feed motion gives four changes of feed, instantly made by lever, and these can be stopped or started instantly by an expanding friction clutch operated by lever, this feature being a great time saver. There is also slow hand feed by wheel, and lever feed for sensitive drilling, the feed worm being provided with a ball thrust. Automatic stop motion to spindle is provided; and the stop can be quickly set for depth of hole without any calculation.

The table revolves on a centre pin or stud, and is arranged to swing round the column. It has vertical adjustment by hand wheel, bevels, and screw, and a ball thrust, which thus makes elevating rapid and easy. The base plate, forked and having tee slots, is for use with large work when the table is swung out of the way. Fast and loose pulleys and belt shifter are provided on the base, as well as channels for lubricant.

The 3ft. combined sensitive and radial drilling machine is illustrated in Fig. 3. The special features of this design are the combination of sensitive and radial drilling, all-gear drive, a new form of saddle carried on rollers, improved reversing motion for tapping on the saddle, and a new device for instantly engaging the feed. As a sensitive drilling machine the hand lever feed can be used for rapidly drilling small holes, and the radial movement enables the arm to be swung quickly into position. The spindle, which is graduated in 16ths of an inch, can be raised or lowered, started, stopped,

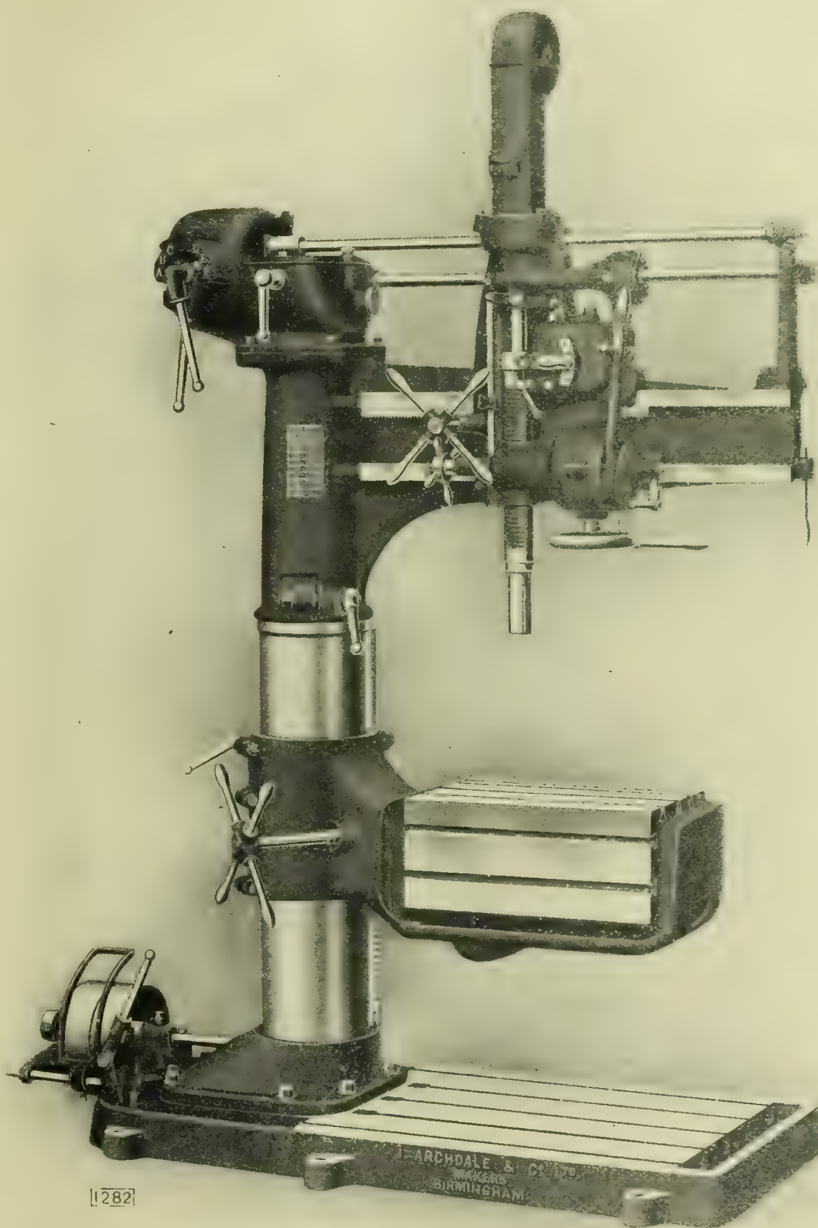


FIG. 3.—COMBINED SENSITIVE AND RADIAL DRILLING MACHINE. MESSRS. JAMES ARCHDALE & CO., LTD., BIRMINGHAM

reversed, feed altered, saddle moved along arm by levers and handles on saddle, and arm adjusted rapidly, whilst running at the highest speed.

As will be seen the machine is gear driven from a constant speed belt, and a change speed box of the sliding-wheel type is fitted on the arm, giving nine spindle speeds by the movement of levers within easy reach of the operator.

The 9in. capstan lathe, as will be seen by a reference to the accompanying illustration (Fig. 4), is a massive and compact tool, and has been designed for dealing with bars up to 3½in. diam., or for chuck work from forgings or castings, particularly where screw threads require to be cut (either

external or internal), the improved chasing gear to saddle, to be described, enabling this to be done with accuracy. Another feature of the lathe is that the feed motion to the turret and saddle is positively driven by gearing.

The headstock gearing is driven by a constant speed belt through spur gears, and by a combination of sliding wheels and friction clutches actuated by lever movement, 18 changes of speed are obtained in either direction, the changes from single to double gear, and reverse, being made without stopping the lathe. The saddle has self-acting, sliding, and surfacing motions, governed by the lever shown in front of the saddle, and it is, we are informed, impossible to engage both motions at once. The tool slide has front and rear tool holders, and is fitted with hand traverse by rack and pinion, geared to ensure ease of movement. Adjustable knock-off and dead stops are also provided for the self-acting longitudinal and transverse motions of saddle and tool slide.

The chasing gear, previously mentioned, enables threads to be cut with great accuracy. It consists of a short guide screw, carried on a front shaft driven by gearing from the spindle, and is clearly shown in the illustration. This guide screw is made in the form of a detachable sleeve, which can be readily removed, and by means of three changes of speed which can be given to it, it is possible to cut screws having $\frac{1}{1}$, $\frac{1}{2}$, and $\frac{1}{4}$ its pitch. Both the guide screw, sliding motion, and capstan feed shafts are positively driven from headstock by gearing. Reversing motion is provided, controlled by lever, for cutting right or left-hand threads from the same guide screw and nut, and adjustable indices are fitted to the longitudinal and transverse movements of saddle and tool slide. The capstan is hexagonal in form, and revolves automatically by star handle, a handle being provided for clamping the turret block to slide. The turret slide has a self-acting traverse of $15\frac{1}{2}$in., and automatic stop mechanism with revolving self-selecting stops for each tool. Gear-driven feed motions are provided to capstan and saddle, and these have each nine changes, altered instantly by the movement of levers in front. Levers controlling feed motion of saddle also control feed motion of capstan.

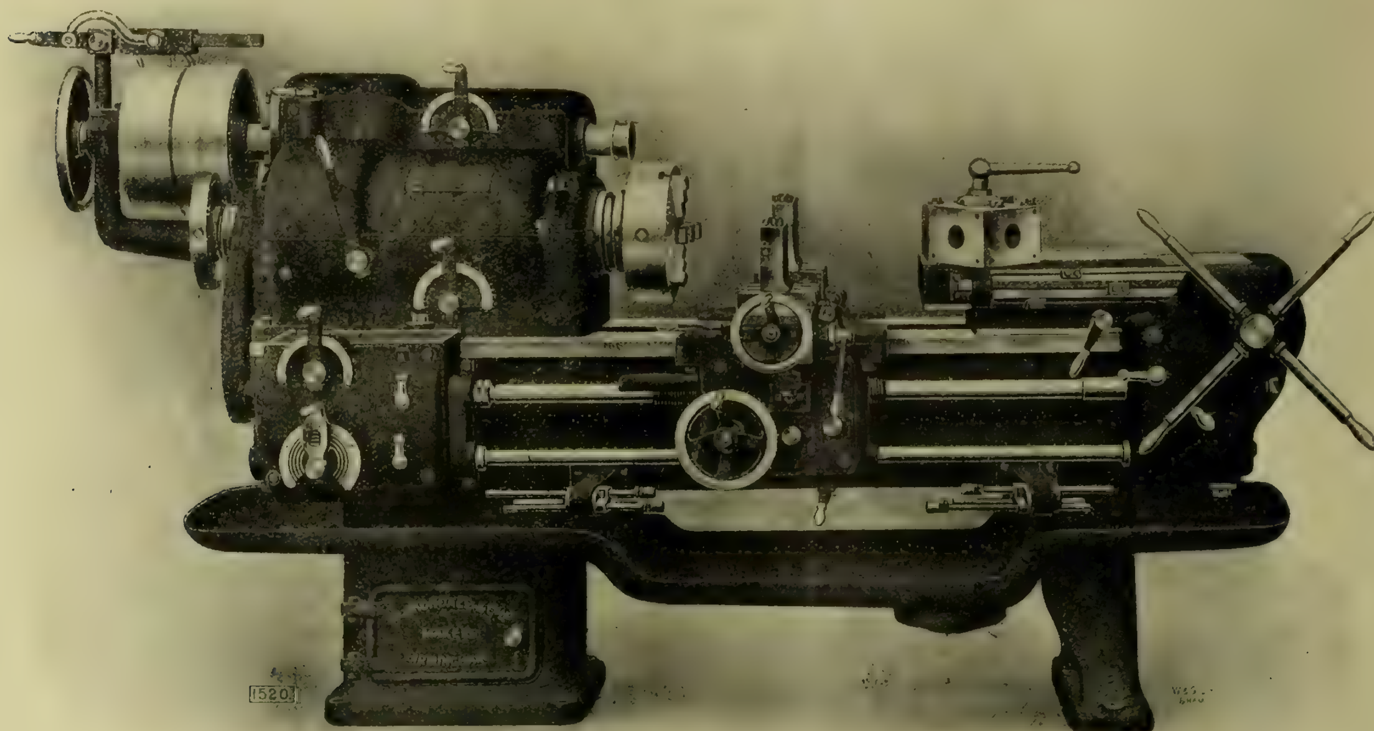


FIG. 4.—HIGH-SPEED 9IN. CENTRE CAPSTAN LATHE. MESSRS. JAMES ARCHDALE & CO., LTD., BIRMINGHAM.

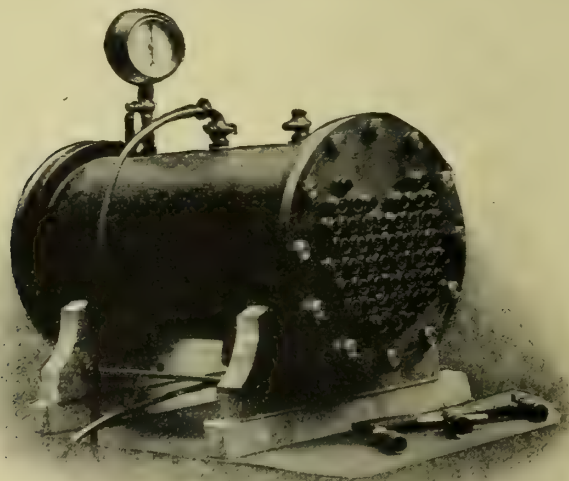


FIG. 5.—PHOTO OF EXHIBITON CONDENSER, FITTED WITH L.E.B. FERRULES. MESSRS. THE L.E.B. ENGINEERING COMPANY, LTD., LONDON.

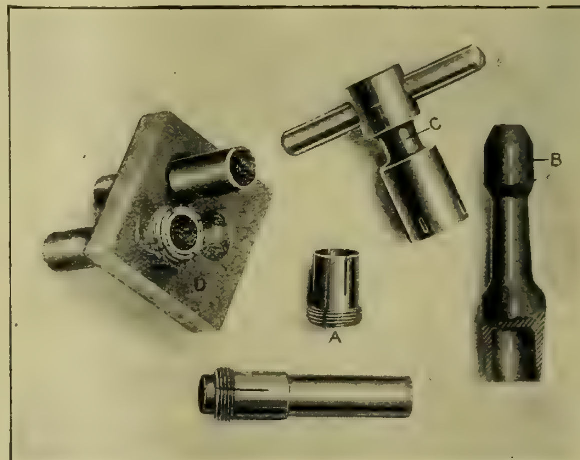


FIG. 6.—PARTS OF L.E.B. CONDENSER FERRULE OUTFIT. MESSRS. THE L.E.B. ENGINEERING COMPANY, LTD., LONDON.

Messrs. The L.E.B. Engineering Company, Ltd., of 68, Pentonville Road, London, N., exhibited a model surface condenser, showing a new method of fixing tubes. The method consists in the use of flexible brass ferrules, which automatically adapt themselves to the tube and tube plate, ensuring a perfectly tight all-metal joint, without the use of soft packing. These joints can be made instantaneously, and removed or replaced when necessary in a fraction of the time required for ordinary screwed or wood ferrules. In the model shown, which we have pleasure in illustrating in Fig. 5, a pressure of 25lbs. per square inch could be applied on the steam side; so that visitors could see the efficiency of the ferrules. The method of using the ferrules was also shown, together with specimens of ferrules, and the necessary tools for fixing and removing them.

In Fig. 6 are shown the various parts of the outfit, A being the elastic tapered ferrule, B a drift, C a drawing key, and D a portion of tube plate. The ferrule A is made with a Morse taper, and the tube plate is reamed to the same taper. The ferrule is also slit in such a manner from each end that the slits pass one another but do not meet. In this way the ferrule becomes elastic, and when tapped home by a light blow closes down on the tube and completely fills the hole, making a water-tight joint. The drawing key C is simply screwed down against the tube plate, and so draws the ferrule straight out, without damaging it.

Owing to the simple process of reaming a tapered hole, in place of drilling and tapping the recess necessary with ordinary brass ferrules, it will be seen that the ferrule under notice is far more economical than a screwed one, and that a condenser may be fitted up in a small fraction of the time hitherto required.

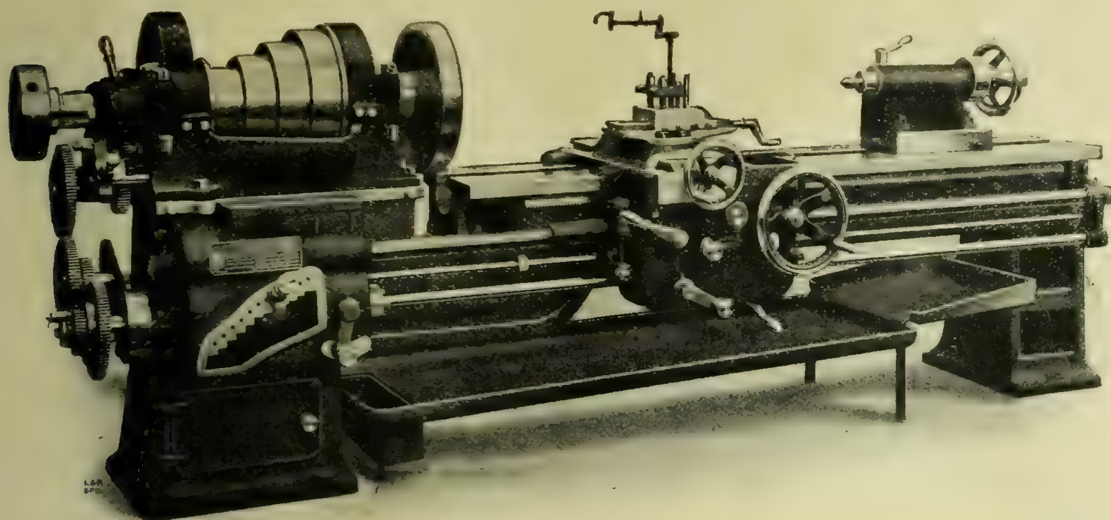


FIG. 7.—8½IN. HIGH-SPEED GAP LATHE. MESSRS. DENHAM'S ENGINEERING COMPANY, LTD., HALIFAX.

Messrs. Denham's Engineering Company, Ltd., of 98, Queen's Road, Halifax, exhibited a collection of lathes and slotting machines, in which class of tool they specialise, and from amongst these we select for special description an 8½in. high-speed gap lathe, a 19in. swing high-speed turret lathe, and a 6in. stroke slotting machine. The first-mentioned machine is illustrated in Fig 7, and its general design will be understood from this photo view. As will be noticed the bed top is quite flat, a second tier being provided for the support of the apron, whilst the edges of the top are square for the guidance of the carriage. The spindle, which has a 3⅛in. hole through the centre, runs in parallel gun-metal bearings, which are adjustable and self-oiling, whilst the end thrust is taken against the front housing by a dust-proof ball thrust bearing. An end chuck is also provided to the spindle for use in steadying bars.

The loose headstock is of the cut-away type, and is fitted with a steel spindle which goes right through the hand wheel, thus giving a full bearing for the spindle when out at its maximum position. The head can also be set over for taper turning, whilst the shoe fits into the bed the whole of its length.

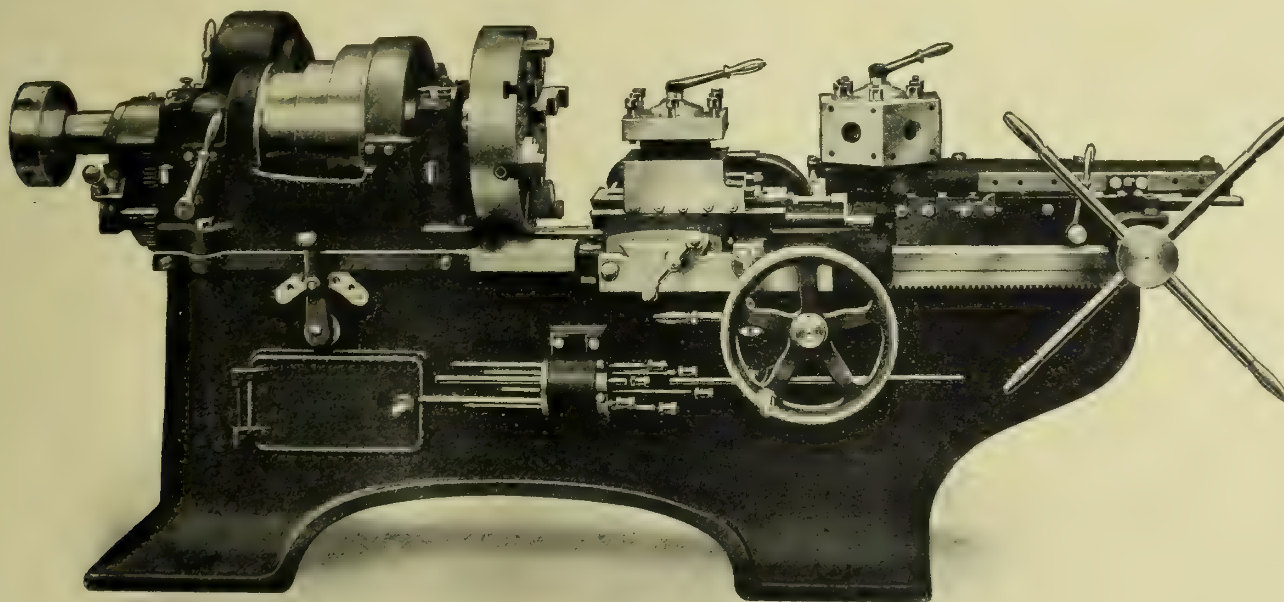


FIG. 8.—19IN. SWING TURRET LATHE. MESSRS. DENHAM'S ENGINEERING COMPANY, LTD., HALIFAX.

The adjustment of the carriage is by taper gib. It is provided with 24 different rates of automatic feed for sliding and surfacing, both operated from the same handle by dropping worm, an instantaneous trip being provided for the sliding motion. All gears are of steel, and the screw-cutting motion

and feed motions are interlocking, thus making it accident proof. A slipping device is also fitted which prevents breakage in case of overloading. The leading screw is stationary whilst sliding or surfacing, and when screw-cutting the feed shaft is stationary. A swing plate is fitted in the usual way, and if a special screw is required to be cut beyond the capacity of the gear box, change wheels can be used in the usual manner. A chasing dial is also fitted to the carriage, which enables the

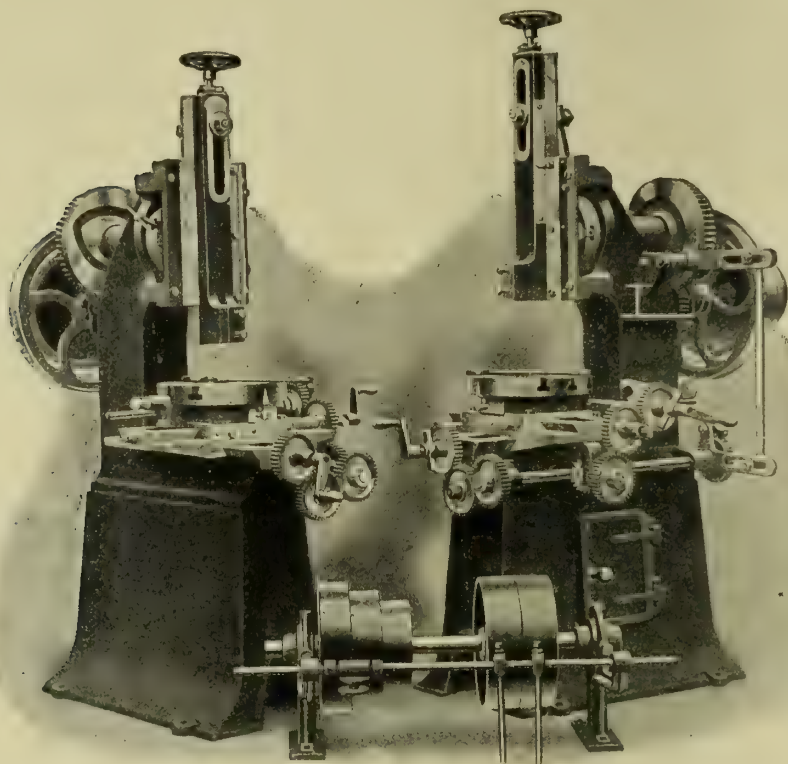


FIG. 9.—6IN. STROKE SLOTTING MACHINE. MESSRS. DENHAM'S ENGINEERING CO., LTD., HALIFAX.

operator to catch the proper intervals of the leading screw quite easily when cutting odd threads.

Fig. 8 shows Messrs. Denham's 19in. swing turret lathe. As will be seen it is of massive design, and like the above-described lathe is fitted with flat-topped bed having square edges for the guidance of the carriage. The headstock also is of practically the same design. On the saddle is mounted either an open-sided square turret or an hexagonal turret. Three rates of feed are provided for sliding and surfacing, positive clutches being used, controlled from the front of the lathe, the feeds being changed with the lathe in motion. If desired, a central boring slide can be fitted, carrying an hexagonal turret, in which case a square turret would be fitted to the saddle. This slide may have either automatic or hand feed, three rates of feed being provided if automatic, quick hand traverse being obtained by pilot handle. The turret slide can also be securely locked for use as a loose headstock.

The gauging arrangement shown on the front of the bed can also be supplied if desired. This consists of six dead stops for lengths, and six dead stops for diameters, each stop having fine adjustment, thus making it possible to gauge lengths and diameters to a very fine degree of accuracy. One dead stop is also provided for the boring slide, for depths when boring.

The 6in. slotting machine we illustrate in Fig. 9, two sides of this machine being shown in the one illustration. The body, as will be observed, is of box section, and is fitted with shelves to carry the operator's gauges, small tools, &c. Driving is by spur gearing and 3-speed cone, a heavy flywheel being also fitted. The disc, which works in a seating bored out of the main casting, is graduated to indicate the exact stroke of the ram, the adjustment of stroke being obtained by means of a screw and nut running in the usual ⊥ slot in the disc.

The circular table has longitudinal, transverse, and circular motions, all self-acting and driven from a cam on the large gear wheel, and each can be engaged independently of the others. The table is indexed around its circumference, and a plunger, and equally-divided plunger holes in the table, make it possible for work to be slotted on two, three, four, six, or 12 equal sides. It may also be adapted to the special requirements of a customer.

A canting motion can also, we understand, be fitted to the circular table when required, giving $\frac{1}{16}$in., $\frac{1}{8}$in., $\frac{3}{16}$in., or $\frac{1}{4}$in. taper per foot at will, for slotting keyways with a taper.

Messrs. W. Silversteen & Co., of 147, Cannon Street, London, E.C., exhibited lifting magnets for different loads, with all the necessary mechanical and electrical fittings. This firm have specialised in electro-magnetic tools and appliances; and, as well as lifting magnets, they exhibited de-magnetising apparatus, eye-magnets for extracting particles of iron or steel from the eye, and electro-magnetic chucks. The latter were shown in several shapes, and to suit various classes of machine tools, such as lathes, planers, shapers, and millers.

Messrs. The Skefko Ball-bearing Company, Ltd., of Luton, Bedfordshire, had an interesting exhibit of ball bearings on Stand No. 347. Probably the most noticeable feature of this exhibit was a short length of 1$\frac{1}{4}$in. shafting which had purposely been badly deflected, but was running freely in two Skefko plummer blocks, fitted with their self-aligning, double row, radial ball bearings. It would have been absolutely impossible for this shaft to have run in an ordinary rigid ball or plain bearing, so badly was it bent, and it formed a striking proof of the automatic and practically frictionless alignment possessed by their bearings.

The balls used in the manufacture of their bearings are, we are informed, guaranteed accurate to the one-ten-thousandth of an inch; they are made from cast steel of the highest quality, produced from the purest Swedish ore, hardened throughout, and tempered by a special process, involving five distinct operations which give the requisite hardness and density without brittleness, and are carried in frictionless

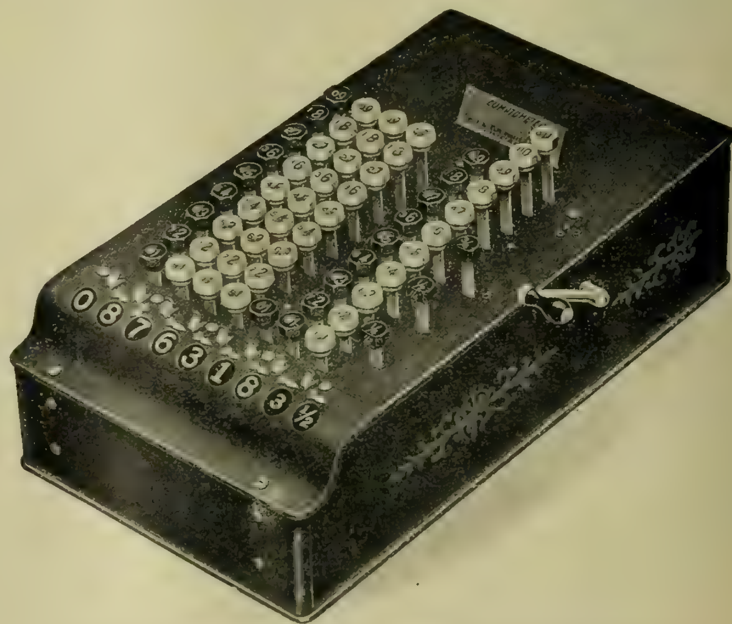


FIG. 10.—COMPTOMETER. MESSRS. THE FELT AND TARRANT MANUFACTURING COMPANY, LONDON.

cages made in one piece, which allow of their easy removal and replacement. The races are ground to the most accurate dimensions, are highly polished, are absolutely free from lateral grooves, holes, or flaws, and are ground to the correct

radii to retain the balls, and present a uniform bearing surface on both ball races. The complete bearing is also self-contained, and is simple to install. It will, it is claimed, withstand a considerable axial thrust without loss of efficiency, and will accommodate itself to all deflections of the shaft upon which it is mounted. It is fitted with the maximum number of balls, three of which carry the bulk of the radial load at any given moment against the usual one only.

Messrs. Major, Robinson, & Co., Ltd., of 213, Deansgate, Manchester, exhibited one of their patent pipe and tube bending machines, complete with blocks for bending various size tubes from ½in. to 2in. Samples of various pipes and tubes, as bent in the machine, were also shown. The tubes, &c., are bent in the cold state, and without the use of filling. It is, of course, equally adaptable for bending solid round bars of iron or steel, and these it will take up to 1¼in. diam.

Several useful cements and compounds of the firm's manufacture, were also shown. Amongst these we may mention their "Skolz" elastic cement, for treating the inside seams of boilers, tanks, &c., and for repairing all kinds of leaks: "Skolz" traction pole cement, for use in fitting up socket joints in tramway traction, and other poles erected in sections: "Skolz" graphite pipe joint compound, for making perfectly tight joints in steam, gas, air, or water pipes, tanks, connections, &c.: "Skolz" flange compound, for making tight flange joints, the contraction and expansion being the same as iron: and "Skolz" iron cement. This latter is a very useful compound. When slightly moistened with a few drops of clean water, and mixed to the consistency of a stiff putty, it will fill out any form, or fill up any defect in a casting, adhering permanently, and becoming part of it. After a few hours it will be nearly as hard as the casting itself, and it continues to harden for months afterwards. In colour it is dark grey, and after it has got hard cannot be distinguished from the article it is used upon. It is, it is claimed, unaffected by oils, heat, various acids, &c., the contraction and expansion are the same as iron, and it can be finished and filed up, presenting quite a bright appearance afterwards.

Messrs. Felt & Tarrant Manufacturing Company, of Bank Buildings, Kingsway, London, exhibited several types of their now well-known "Comptometer," an instrument for performing with accuracy all kinds of addition, subtraction, multiplication, and division. Three types of machine were shown, viz., the British currency or duodecimal model, giving answers in pounds, shillings, pence, and farthings; the fraction model, having the first column at the right for adding fractions in eighths; and a decimal model, giving answers in whole number and decimals. Each machine is made with either 8, 10, or 12 columns as desired, and is small, light, strong, compact, and very neatly finished. They measure only 5in. to the top of the keys, and weigh but 15lbs. or so.

To indicate what may be done with the machines, perhaps we cannot do better than give a few examples, with the time taken to perform same. Thus: *Wages*—54½ hours at 9¼d. per hour = £2. 2s.; time, 3 seconds. *Tonnage*—15 tons 6 cwts. 1 qr. 19lbs. at 49s. 4d. per ton = £37. 15s. 10d.; time, 3 seconds. *Exchange*—$1,753.45 at 4·87½ = £359. 13s. 8d.; time, 5 seconds. 3545·25 fr. at 25·15¾ = £140. 18s. 5¼d., time, 10 seconds. *Percentage*—£486. 12s. 6d. less 3¼ per cent. = £470. 16s. 2¼d.; time 10 seconds. *Interest*—£378. 10s. 8d. at 3½ per cent. for 288 days = £10. 9s. 1d.; time, 25 seconds. 6,327 × 6,457 = 40,853,439; time, 5 seconds. 263 × 879 × 138 = 31,902,426; time, 9 seconds; and so on.

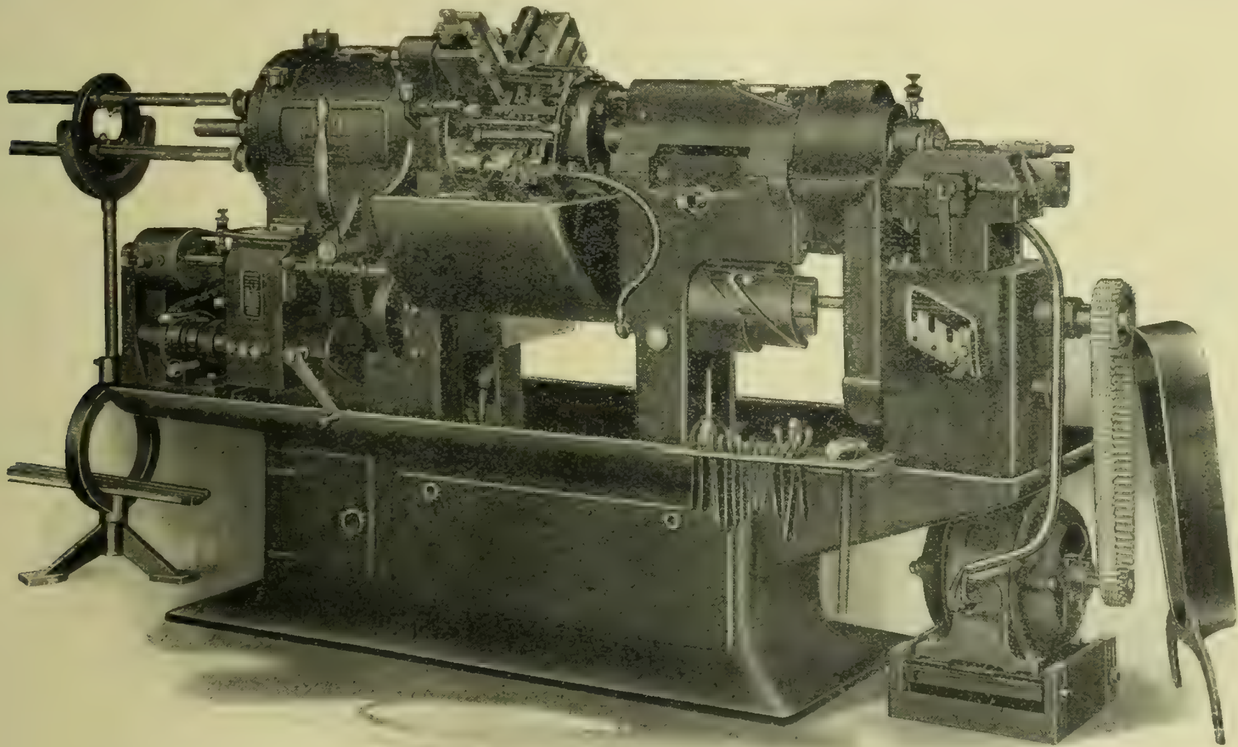


Fig. 11.—Lester 4 Spindle Automatic Screw Machine (Front View). Messrs. C. W. Burton, Griffiths & Co., London.

The Comptometer keyboard, as will be noticed by reference to Fig. 10, is extremely simple. In the duodecimal Comptometer with farthings, the first column on the right is for farthings 1 to 3, in the second column are pence from 1 to 11, in the third column are units of shillings from 1 to 9, in the fourth column are tens of shillings, in the fifth column are units of pounds from 1 to 9, in the sixth column are tens of pounds from 1 to 9, and so on across the keyboard.

Addition is performed by merely depressing the keys corresponding to the numbers to be added. To add, say, £18. 15s. 10d. strike the 1 key in the sixth column, the 8 key in the fifth column, the 1 key in the fourth column, the 5 key in the third column, and the 10 key in the second column—when the amount appears on the register.

To multiply, take one number on the keys and count the strokes as indicated by the digits of the other number. For example, to multiply 578 by 463; since the duplex feature permits the striking of any number of keys at the same time, place the fingers on 578 and strike three times: move one column to the left and strike six times; moving once more to the left strike four times—when you have the answer, 267,614, in the register. A very little use of the machine gives amazing speed on multiplication, and if there be a

decimal point in either of the factors, they are simply pointed off in the same way as when figuring with pencil and paper.

On the duodecimal Comptometer, amounts in British currency can also be quickly, easily, and accurately multiplied by either whole numbers or decimals. The pounds columns in such a machine are naturally the same as the decimal columns on a machine which is wholly arranged for decimals, and so the pounds columns can be used for adding or figuring anything in decimals. In this way all computations in decimals and duodecimals can be done on one and the same machine.

Division and Subtraction.—Each key bears on its top a small figure which indicates the power of that key for subtracting and dividing. These operations are the converse of adding and multiplying. Discounts are also figured with reference to the small figures on the key tops.

The lever on the side is used only to cancel or set the machine at naught, preparatory to beginning a new addition or calculation.

If a wrong key should be touched by mistake, correction of the error can be easily and quickly made. Thus, if a 5 should be struck instead of a 6, the difference is added by striking the 1 key; or, if 9 is struck instead of 7, simply strike the key which subtracts 2. All odd keys are concave, all even ones smooth; so that from a sense of touch alone the operator is instantly aware of it should a wrong key at rare intervals be struck.

Messrs. C. W. Burton, Griffiths, & Co., of Ludgate Square, London, E.C., had several very large stands, the tools shown forming a fully representative exhibit of the firm's manufactures and of those they factor. So many tools and appliances were shown that it is impossible to do justice to them all in the limited space at our disposal, and indeed it becomes a matter of difficulty to select any one particular tool for special mention, as there were new and important features on almost every machine shown. We, however, illustrate and give a few extended particulars of three of the exhibited machines, together with illustrations and a short description of several smaller tools and appliances, in the hope that they will prove of interest to our readers.

Fig. 11 shows the "Lester" multiple spindle automatic screw machine, which is entirely new, the one exhibited being the first to be shown of its type. It is, the firm claim, an improvement on the "Lester" 3-spindle automatic, a machine they have been selling for some considerable time past. As will be seen, the machine is of the single pulley drive type, the pulley running at a constant speed, there being four spindles carrying the bar stock. The collets have no end movement, thus ensuring accurate feed of stock, whilst the rods can be either fed collectively, the four rods at once, or independently. There are four tool positions in the tool slide, giving four end cuts and four independently operated cross slides, one to each spindle. The tapping and screwing spindle can be applied either in the third or fourth position, or, if necessary, the machine can be fitted with two tapping and screwing spindles, one in the third position and the other in the fourth. The time consumed, we are informed, in drawing tools away from work, feeding the stock, indexing the spindle cylinder, and moving the tool forward again ready to cut, in no case exceeds three seconds, whilst the capacity of the machine is for bars up to 1in. diam.

Fig. 12 shows a "Lapointe" broaching machine exhibited by Messrs. Burton, Griffiths, & Co. These machines, which are made in four sizes, are for broaching out holes of irregular shape, and have been found particularly adaptable for the motor industry. A board with samples of holes broached was shown at the Exhibition, and this gave a very good idea of the class of work performed by the machine. The smallest size machine has a capacity for broaching a square hole ½in. square by 2in. long, or for cutting a keyway ⅜in. wide by 4in. long, and the largest machine has a capacity for cutting a keyway 1¼in. wide by 14in. long, or for broaching a 3in. square hole 8in. long. Other holes can of course be broached of proportional sizes. The machines get through the work usually accomplished on the slotting machine in from one-fifteenth to one-twentieth of the time, and for repetition work we should say they are an essential part of a modern machine shop equipment.

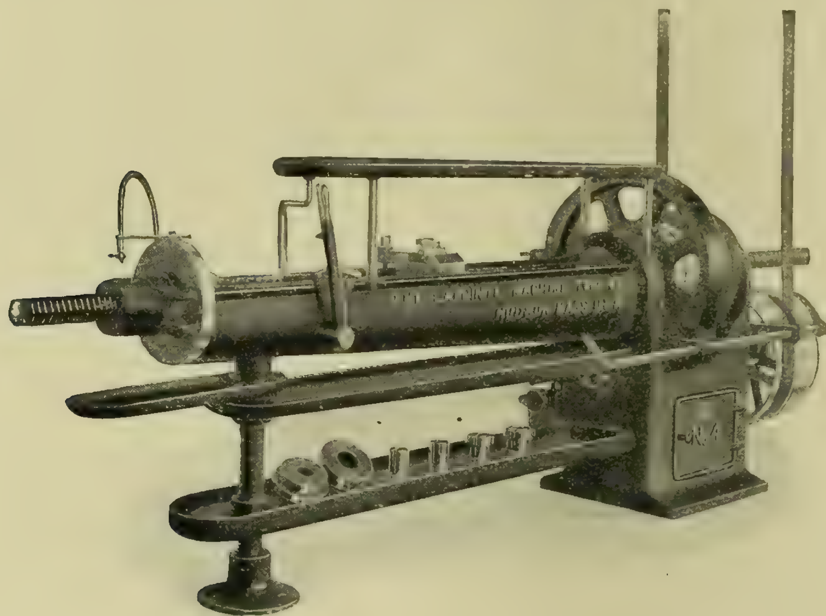


FIG. 12.—"LAPOINTE" NO. 4 BROACHING MACHINE. MESSRS. C. W. BURTON, GRIFFITHS & CO., LONDON.

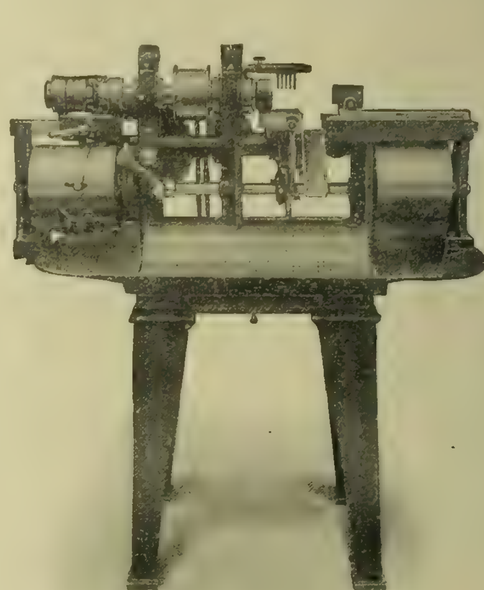


FIG. 13.—"PITTLER" AUTOMATIC PIN AND STUD MACHINE, MODEL A. II. MESSRS. C. W. BURTON, GRIFFITHS & CO., LONDON.

The work to be done requires no fastening whatever to the machine, but is simply slipped on to the work bushing or broach in a loose manner, according to the work to be done. The work then becomes fastened in its proper position as soon as the machine is started. In most cases but one operation is required, and but one minute's time is consumed to cut a keyway in a hole, and sometimes three or four pieces can be done in one operation, thus increasing the production from 25 to 100 pieces per hour. For broaching square holes, or other various shapes, when not over 2in. long, the work can be done in a single operation consuming 1½ to 2 minutes' time, while on longer work the passage of two or three broaches may be necessary, the time of production being of course increased accordingly.

Fig. 13 shows a "Pittler" pin and stud machine, which was exhibited and shown at work turning out screws with round heads, ⅛in. diam. and $\frac{7}{32}$in. long, including the nicking for screwdriver, at the rate of 32 per minute. These machines, we understand, are at present only made in three sizes, viz.: Models A I., A II., and A III., and it is the middle-sized model we illustrate. They have been specially designed and adapted for drilling and cutting off nuts, plain pins, and

similar shaped articles, which can be made from accurately drawn or rough rolled bars of various metals, and in the manufacture of which only three or four tools are necessary. When, however, as at the Exhibition, these machines are provided with a threading attachment, little screws or plain pins may be produced advantageously by them. The machines work quite automatically, so that after the proper setting up of the tools the operator has only to replace the bars as they are used up.

The bed, as will be seen, forms a trough to collect the liquid used for cooling the bars and tools, which liquid is kept in continuous circulation by a small pump. The headstock is provided with automatic feed and collet chucks for holding the bars, which latter are held very rigidly and precisely, as the feeding chuck does not require to be displaced laterally after it has gripped the bar. The automatic movements are effected by cams or drums, the latter carrying spiral segments which transmit the rates of feed desired to the various slides.

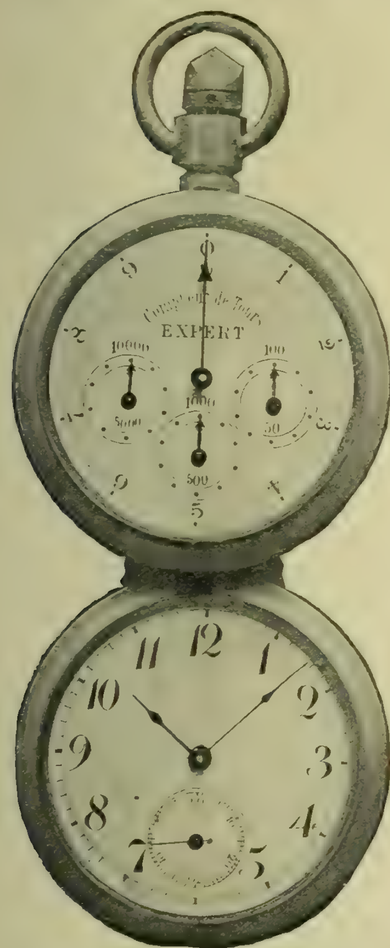


FIG. 14.—"BURTON" WATCH AND SPEED INDICATOR. MESSRS. C. W. BURTON, GRIFFITHS & CO., LONDON.

The cross slide is in two parts and arranged in such a way that the two tools may be made to work together or independently, as desired, the depth of cut of the tools being easily and rapidly regulated by screws. Circular forming and cutting-off tools are used, which may be ground without altering their shape, and the tool posts are adjustable laterally and are provided with teeth which engage with the circular tools so that these tools will not get out of position while working. Upon the cross slide may also be fastened a tool for the ornamentation of the heads of screws, such as a knurler, which is made to roll against the head before cutting off.

The longitudinal slide, intended for one tool, is fed automatically into the work, and is driven by means of the cam shaft, the cams being arranged in such a way that the slide is fed only while the tool is working, the return and idle movements being effected at a much quicker rate. For the boring of rings, nuts, and other pieces the slide is provided with a tool-holder, which may contain, besides a twist drill or other boring tool, a round tool for chamfering, so that boring and chamfering operations may be done at the same time.

From amongst the small tools and appliances, exhibited at a separate stand to the one on which the machine tools were shown, we select the "Burton" watch and speed indicator, the "Perfection" spring winder, a drill speeder, and a "Norton" water motor for special description, and these we illustrate in Figs. 14 to 18. At some later date we hope also to be able to fully illustrate and describe a set of "Johansson" combination standard gauges shown by the firm. The accuracy of these gauges, we should say, is probably higher than has ever before been produced in steel, and is the more remarkable in view of their large surfaces and the fact that they have been brought out as a commercial article intended for daily use in the tool room of an engineering workshop. Such tools cannot fail to excite the greatest praise and admiration.

Fig. 14 illustrates the "Burton" watch and speed indicator, a very compact and handy instrument weighing only some 6 ozs. and capable of registering up to 10,000 revolutions. As will be noticed, the watch is hinged to the counter, and when not in use is folded over and thus forms the back of the instrument.

Figs. 15 and 16 show another ingenious little tool for winding springs. This can be used with either lathe, drill, or vice, and it will wind either compression or extension springs of any length and from any gauge wire, no wire being wasted in the process.

The drill speeder shown by Messrs. Burton, Griffiths is illustrated in Fig. 17. The object of this little device is to drive small drills up to their proper speed while being used in the larger class of drilling machine. The speeder takes up to ½in. drills and has a sensitive feed lever giving about 1¼in. travel, but, when this is not enough, the ordinary feed mechanism may of course be used.

Fig. 18 is an illustration of the "Norton" water motor shown by the firm. These will be found a compact and useful device for obtaining power for running light machinery. They can be used with a pressure of 30lbs. or over of water and develop from ⅛ h.p. to ¼ h.p. Two pulleys are provided, as shown, one at each side of the motor, one of these being geared to run at 1,000 to 1,600 revs. per minute, and the other running at the speed of the main shaft, viz., from 3,000 to 5,000 revs. per minute.

Other useful small tools shown were: Gas-heated soldering irons, new types of lathe carrier, bench grinders, "Third Hand" thumb magnifiers (a useful magnifier which can be clipped to the thumb of the left hand, thus leaving the fingers of each hand free to hold and examine the article), a new slide calliper, new types of wrenches, milling cutter guards, &c., but we have not space to describe these at length. We may, however, in conclusion, call attention to a little novelty shown on the stand in the shape of what is claimed to be the smallest twist drill in the world. This drill was only 0·005in. diam., but nevertheless a real twist drill having milled flutes, and being hardened, ground, and tempered ready for use.

Messrs. Alldays & Onions Pneumatic Engineering Company, Ltd., of Great Western Works, Birmingham, exhibited a representative collection of goods of their manufacture on Stand No. 321. The firm, as our readers will be aware from the notices we have given from time to time, specialise in smithy and foundry equipment, including heaters, fans, blowers, power hammers, cranes, and small tools, as well as furnaces of all classes for forging, hardening, annealing, &c., and fans for mine ventilation and induced draught. The exhibit was a large one, and demonstrations were given at intervals of the furnaces, hammers, fans, &c., shown. All the furnaces were fitted with the firm's patent burner, which we have previously described (see "The Mechanical Engineer" for October 12th, 1907, page 518, Vol. XX.), and a modification of this burner was also shown for hand use for mould drying, local heating, &c.

Mr. William Boby, of Salisbury House, London Wall, London, E.C., exhibited two of his water softeners, one being known as the "Simplex" type, and the other as the type "K" softener. The "Simplex" softener employs re-agents in the form of "cream" of lime and soda, the apparatus distributing the re-agents in accurate proportion to the water to be treated. To ensure the correct amount of chemical being applied to the water, two vessels are provided into which the chemical solution and the water respectively are definitely measured, the vessel containing the chemical solution is then discharged and mixed with the water measured in the water vessel. No valves or floats are employed in the distributing gear. This machine is made in capacities varying from 250 galls. per


FIG. 15.—PERFECTION SPRING WINDER. MESSRS. C. W. BURTON, GRIFFITHS AND CO., LONDON.

hour to as large a capacity as desired. The type "K" machine is a novel form of softener in which re-agents are employed in the form of dry powder, accurately distributed to the water. This type is designed for as small a quantity as 200 galls. per day of 24 hours, and up to a quantity of 4,000 galls. per hour. The device, we are told, has proved to

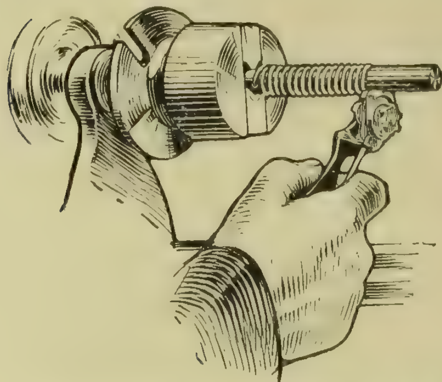


Fig. 16. Showing Perfection Spring Winder used in Conjunction with Lathe. Messrs. C. W. Burton, Griffiths & Co., London.



Fig. 17.—Drill Speeder. Messrs. C. W. Burton, Griffiths & Co., London.

be remarkably accurate, and requires only the slightest amount of attention at infrequent intervals.

Messrs. Scholey & Co., Ltd., of 151, Queen Victoria Street, London, E.C., exhibited motor starting and switch gear, "Scholey" motors for alternating-current or direct-current work, and other electrical devices and novelties. One of the chief departments of the firm, we understand, is the installation of complete plants for electric power driving, as well as switch gear for heavy work; and the departmental catalogue they issue, exclusively devoted to apparatus of this kind, and containing upwards of 50 pages, is evidence of the scope of their work in this direction.

An ingenious little device shown by the firm was the "Hopkins" electric speedometer, several types of which were to be seen on the stand. The principle of operation consists in the use of a small direct-current magneto generator, and an indicating electrical voltmeter, the two parts of the system being connected by two wire insulated cable. By a system of coils rotated within a permanent magnetic field, an electric voltage or potential is generated in direct proportion to the speed of rotation of the moving coils, and it therefore becomes possible to calibrate the electrical voltmeter in terms of speed; in this instance, revolutions per minute.

Other interesting things shown were electric soldering irons, the "Vulcan" electric wax melter, branding irons and similar tools, as well as grid resistances, a type now used by many railway and tramway corporations.

Messrs. André Citroën & Co., of 27, Queen Victoria Street, London, exhibited various types of their now well-known double-helical gears, including one set of single-reduction spur gears, ratio 14·1, diameter of wheel 5ft. (these gears were shown in motion, driven by electric motor); one set of bevel gears of the type used in spinning mills (these gears also were shown in motion, driven by electric motor); one set of three rolling-mill pinions, each pinion weighing three tons; and one set of double-reduction gear, consisting of spur and bevel gears contained in gear box (this gearing was arranged to be worked by hand). The centre of the stand was occupied by a large ring-shaped spur wheel, made in wood, some 16ft. diam., and cut on the face with double herringbone teeth of 8in. pitch and 20in. in width. This formed a very effective and striking exhibit. The Citroen spur and bevel gears can, we are given to understand, be made up to 20ft. diam. and 3ft. in width, and can be cut to any pitch, with an unlimited maximum. The minimum limit is, however, $\frac{5}{16}$in. pitch, for cast iron and gun-metal, and $\frac{3}{8}$in. pitch for steel.

Messrs. Smith & Coventry, Ltd., of Gresley Iron Works, Ordsall Lane, Salford, had a large exhibit of machine tools of their manufacture, and one of these we have pleasure in illustrating in Fig. 19. This is a Roby-Smith patent bevel gear planer, a machine capable of cutting mitre wheels up to 16in. pitch diameter, and bevels up to 17½in. pitch diameter, between the ratios of 3 to 2 and 6 to 1.

In this machine, which is on the shaping machine principle, two tools are used, one on each side of the tooth. These tools are carried on slides on pivoted arms, which converge on a centre intersecting the apex of the wheel to be cut. The tools move backwards and forwards on the slides on the pivoted arms, the backward movement being accelerated, and at the same time the pivoted arms are gradually opened and closed so that the distance between the cutting tools is varied, and a curve formed on the tooth being cut.

It will be seen by referring to the illustration that the saddle carrying the blank to be cut has a rotary motion, the centre being directly under the apex of the blank to be cut. This rotary motion of the saddle feeds the blank to the tools, and is automatically stopped when the proper depth of tooth has been cut. The saddle also, it will be observed, is connected with the pivoted arms carrying the slides and cutting tools by a circular bar having teeth cut in a portion of its circumference. These teeth engage into a quadrant, which, through a pair of bevel wheels and slotted lever, operating through a connecting rod, control the swinging parallel motion which in turn controls the pivoted arms.

The blank is rotated the distance of the pitch for each stroke of the tools, thus preventing the local heating common in machines which complete one space at a time, and it also tends to eliminate errors due to wear of cutting tools. Indexes are provided at all points where adjustment has to be made, so that little skill is demanded of the workman when handling the machine.

The machine, as will be noticed, is driven from a three-speeded cone and single gear through a disc connected with a slide. From this slide two connecting rods convey the shaping motion to the two slides carrying the tools, which motion is accelerated in the return stroke. It has been previously explained that the slides carrying the tools are in their turn carried on pivoted arms which open and close, as do the blades in a pair of scissors, through the action of the parallel motion controlled from the saddle. To remove undue strains caused by the tendency of these arms to drop, mechanism (protected by patent) has been introduced, whereby they keep each other in absolute balance, rendering possible much quicker manipulation of these parts when setting the machine, as well as the production of better work.

For dividing, 21 dividing plates are supplied for dividing all numbers up to 50; also 24 others for numbers from 51 to 120. They are made with two separate sets of notches, one



Fig. 18. Norton Water Motor, showing slow-speed geared pulley detached. Messrs. C. W. Burton, Griffiths & Co., London.

set being used for pushing the plate round and the other for dividing only. Those with the greater number of teeth are made in steel, and all, we understand, are cut from the solid.

Other machines shown by Messrs. Smith & Coventry, Ltd., were a 3ft. by 3ft. by 10ft. "New" planing machine (Bateman's patent) having three tools, *i.e.*, two on cross slide, and one on upright; a 4ft. turning and boring mill; an Austin patent automatic chucking machine; an 8in. Cooper patent brassfinisher's lathe; and pneumatic hammers.

The principal feature of the "New" planing machine is its high efficiency, only a very small fractional loss of time taking place when the table reverses, while the table travels at its full speed practically the whole length of the stroke, both cutting and returning. In testing a 4ft. machine on a 12ft. stroke, it was found that, over 10 cycles of the table, the high efficiency of 98·33 per cent. was attained. This result is due

to the use of flywheel energy, which is utilised to its fullest extent, in combination with an almost instantaneous change from the driving to the reverse gears, and an absence of belt shifting. The belts run constantly in one direction, and have not to be shifted from one pulley to another, and the usual uneven strain at the time of reversal is taken off them by the action of the flywheels. The accuracy of this statement is seen in the fact that a 2in. belt will drive a machine to plane 4ft. by 4ft. by 12ft. using three tools and taking the heaviest cuts.

Two flywheels are employed, one on either side of the machine. These are continuously driven by open belts, and are alternately coupled up to the cutting and return trains of gear by means of bands, which are carried in the flywheels, these being instantly brought into contact with the peripheries of pulleys keyed on to the driving shafts. On the cutting side there is, in addition, a positive clutch connection between the flywheel and the pulley, which is brought into use automatically immediately the reverse, preceding the cutting stroke, is completed. Both cutting and return belts run in the same direction, so that the flywheel on the cutting side has the assistance of the flywheel on the return side when cutting and vice versa.

The turning and boring mill exhibited had a table 46in. diam., which was driven by spur gearing of nearly the same diameter, and would admit work 48in. diam. by 38in. height. The cross slide carried two heads, each of these being independent, both as regards feed and movement. Each head was capable of swivelling on the saddle through an angle of 45° either side of centre, and the saddles and rams could be operated from either end of the cross slide, indexed dials being provided on each screw and feed rod graduated to $\frac{1}{1000}$in. The toolholders of these machines are quickly fixed in position and, we noticed, will pass inside the slide, thus allowing the heads to get close down to the work.

THE SEASON-CRACKING OF BRASS AND OTHER NON-FERROUS METALS AND ALLOYS.

BY ERWIN S. SPERRY.

WITHOUT question, the season-cracking of brass is the most exasperating of any of the difficulties to which it is subject. It is exasperating for the reason that it rarely occurs while the brass is in the mill of the manufacturer who makes it. Indeed, it may be said that season-cracking takes place so seldom in his mill that when it actually does occur, on extremely rare occasions, it is worthy of note. Many of the workmen in a brass rolling mill making sheet, rod, wire, or tubing have never seen a case of season-cracking, except, perhaps, that which may have been noticed on scrap returned. They are familiar with fire-cracks, but season-cracking is a new phenomenon to them. It is the customer of the brass rolling mill who has the difficulty and it is for this very reason that it is so annoying when it does occur. It may happen several years after the brass has been purchased and goods have been made up. It may season-crack after made up into various articles and sent broadcast over the country to the consumer. If the article thus made of brass is cheap nothing is said about it, but if expensive goods are made up, then the customer brings the matter before the manufacturer of the goods who, in turn, considers that the brass is at fault and comes back at the brass rolling mill with some pointed remarks about the quality of his metal. When goods season-crack in such a manner it is an extremely difficult matter to convince the manufacturer who made them from sheet or other form of brass, that the brass is not to blame. There are, of course, occasions when it may be, if tubing is used as it is possible, by uneven drawing to produce internal strains which *may* result in season-cracking. Sheet metal is not subject to it and wire cracks when made into springs, fatigued and subjected to repeated vibration. While analagous to season-cracking, and perhaps is identical with it, this phenomenon is called "crystallisation" and, possibly, season-cracking is the same thing. The cause may be different, however, but the effect seems to be almost identical.

The manufacturer who purchases sheet brass from a reput-

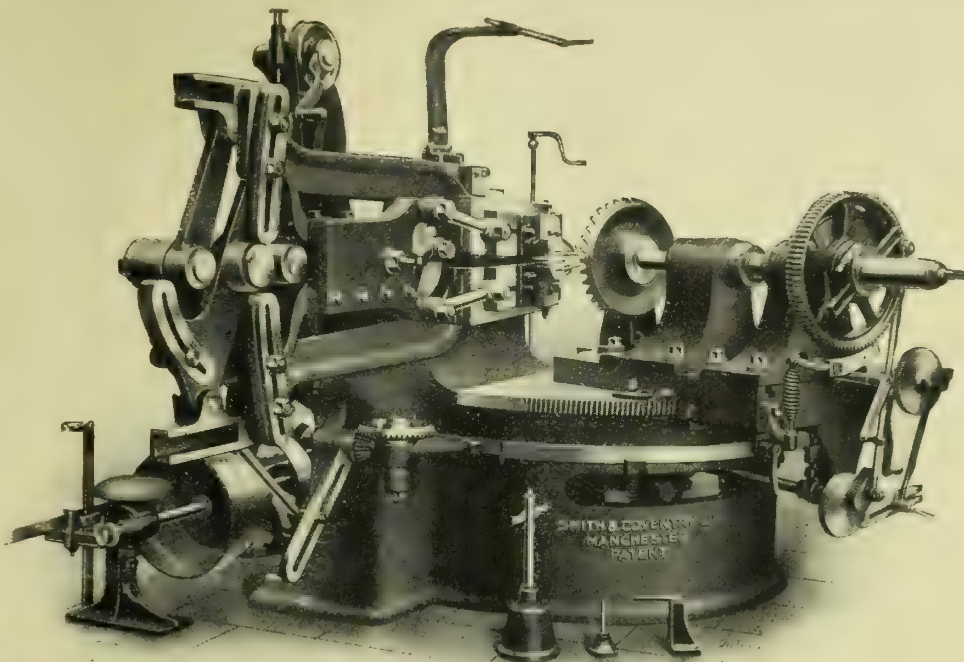


FIG. 19.—ROBY-SMITH BEVEL GEAR PLANER. MESSRS. SMITH & COVENTRY, LTD., SALFORD.

able rolling mill, makes it into wares, and when these have been made and have been in stock for some time, finds that they have cracked badly is quite apt to blame the manufacturer of the sheet brass. He knows that the goods were all right when they were finished, and when packed in boxes and put on his shelves in the store-room were likewise perfect, so that when, after, perhaps a number of months, he finds that the goods are cracked (possibly every one of them) he naturally believes that the fault lies with the maker of the sheet brass. From the time brass sheet began to be made this difficulty has occurred, and the manufacturer has, it is believed, been unduly censured and in many instances subjected to treatment not due to him. Rather than have any controversy, "broad gauge" manufacturers have been known to take back such season-cracked brass and pay for the labour put upon it. This, however, was in the past, when little was known of the cause of season-cracking, and the brass rolling mill proprietor was somewhat dubious about the real cause of the cracks. He faintly imagined that there was a remote possibility of the difficulty actually being caused by imperfect treatment of the brass at his rolling mill, so he granted the demands of his customer and allowed his claim. As a question of policy this may have been all right, but to-day the matter is different. When the user of the brass sheet finds that his goods are season-cracked and the rolling mill can give him no reason for it, it is not surprising that he should firmly believe that the fault lies with the sheet brass; but when it is possible to get to him and say: "Your difficulty is in the shape of your dies, or in the way the goods are annealed, or in the fact that you are using mercury in preparing the goods for electroplating," then it is possible to demonstrate to him that he and not the brass itself is the cause.

Such is the state of the art to-day and the greater our knowledge of the cause of such a phenomenon as season-cracking, the more manufacturing becomes simplified. It serves to close the gap that has always existed between the rolling mill and the manufacturer who cuts up the brass and makes it into articles for the trade. The excuse for writing this article is the fact that little has been known about season-cracking being caused by mercury. To be sure it has been known for some time among certain of the brass rolling mills, but as general knowledge it has not existed. As far as known,

the fact that mercury will bring about season-cracking has never before been published, and it is believed to be a more frequent source of season-cracking than is imagined. Mercury is extensively used in electroplating. More particularly in silver plating, perhaps, and it will readily be appreciated that a large amount of it is done. It is hoped, therefore, that this article may serve to explain some of the perplexing instances of cracking that occur on silver-plated goods. Before entering into the details of the phenomenon, let me explain what season-cracking is: —

Season-cracks are those which occur in brass or other metals when the article upon which they occur is not in use or, in other words, is at rest. If in motion, the phenomenon is called "crystallisation" and there seems to be a very close connection between the two. The cracks may make their appearance soon after the goods have been made, or they may occur long afterwards. Ordinary season-cracking may be caused by internal strains in the goods. For example, a seamless brass tube that has been compressed, while being drawn through the die on a drawbench more on the outside than on the inside, and particularly if the brass has been drawn very hard so as to almost fatigue the metal will often crack on standing. The same is true of brass sheet after being drawn in a press in which the die and punch are so made that the metal is not stretched at all, but simply formed into shape. This puts strains in the metal. Another cause is the action of various chemicals such as ammonia or its compounds. Season-cracking, therefore, may be defined as that which takes place without any apparent outside influence and *per se*. It is supposed to occur spontaneously. Ordinary season-cracking occurs in yellow brass, although German-silver and other alloys containing zinc are subject to it. The red metals are not apt to crack, although now and then instances are known where they have done so. Even copper has been known to develop the difficulty. With mercury, as will subsequently be explained, the season-cracking may take place with all the non-ferrous metals.

One may naturally ask the question: From what source does the mercury come? Is it in the brass, or used in its manufacture? In reply it may be said that it comes from two sources. (1) From mercury salts used in a solution for preparing brass or other non-ferrous metals for silver or gold plating. This solution is known as a "quick-dip" or a "blue-dip." It contains some salt of mercury in solution. The brass or other metal is dipped into it and becomes coated with a film of mercury. The longer it is allowed to remain in the solution, the more mercury will adhere to the surface. The article is then silver plated. The mercury serves to bind the silver to the base metal and it is customary and has been for many years to use such a solution in silver plating. It prevents the silver from peeling while the articles are in use, and while it is possible to silver plate without it, it is considered standard practice and the safest to use the mercury dip previous to depositing the silver. (2) From mercury compounds, such as ointments, pastes containing mercury salts as a preservative and other chemicals containing mercury that may come in contact with the brass or other non-ferrous metal in some way or another.

It has been known for some time that mercury would cause the season-cracking of brass, but whether it would have a similar effect on other non-ferrous metals was uncertain. It was deemed advisable, therefore, to make some experiments in order to ascertain whether the effect was similar to that of brass. It was found that all the non-ferrous alloys are affected in a similar manner.

To test the effect of mercury on the various non-ferrous alloys, samples of various shapes were taken and coated with a slight film of mercury and then allowed to stand. It was found that the mercury did not penetrate the metal immediately, but after a few hours the effect was noticeable. A longer time produced a greater penetration. After having remained for several hours, the article was bent slightly when the cracking took place. The samples tested comprised: (1) A seamless brass tube, made of high brass. When squeezed slightly in a vice, the cracking took place. The tube was hard drawn. (2) A brazed brass tube of low brass. This tube was annealed before treating and when bent or flattened the cracking took place. It is apparent that the effect of the mercury is more manifest on hard drawn brass than upon soft metal. (3) A No. 8 B. & S. gauge German-silver wire. It contained 10 per cent. of nickel. When slightly bent after treating with mercury, fracture took place. The wire was soft and the effect of the mercury was quite marked. (4) A piece of seamless phosphor-bronze tubing containing 98 per cent. of copper, 2 per cent. of tin, and a small amount of phosphorus (about 0·05 per cent.). This behaved like the others. (5) Hard rolled high brass sheet. This cracked similarly to the others after treatment with the mercury. (6) Soft sheet copper. This cracked after standing for some time, but unless given from 5 to 24 hours the metal did not appear to be affected appreciably.—"The Brass World."

ELECTRICAL POWER TRANSMISSION FOR SHIP PROPULSION.

AT a meeting of the Society of Engineers (Incorporated), held on the 4th inst., Mr. Wm. P. Durtnall read a paper on "The Generation and Electrical Transmission of Power for Marine Transportation." The author pointed out that the fundamental problem of propulsion was to produce economically a thrust sufficient to overcome the resistance with which a ship meets in moving through the water. It was stated that the earliest attempt at applying mechanical power to propulsion was made by Blasco de Garay, a Spanish navigator, in 1543, and that the screw propeller was introduced about 1835 by Francis P. Smith, a farmer, of Hendon; the "Great Britain" being the first screw-driven boat to cross the Atlantic. Reference was made to the hot-air propelled ship "Ericsson," designed by the famous inventor of that name, and to the method of propulsion by jets of water. A description was also given of the propelling machinery of the "Great Eastern."

The author suggested that the "thermal propulsive efficiency," *i.e.*, the percentage of fuel heat converted into effective thrust at propeller, should be the measure of the commercial value of a ship, especially in the mercantile marine, and he showed that the intermediate losses were often very great. The conditions of speed for effective propulsion by screw propellers were discussed, and the practical requirements which should be met by the prime mover, especially with regard to speed control, were laid down.

The advantages and disadvantages of the steam turbine for marine propulsion were enlarged upon, and it was shown that the latter were by no means inconsiderable, and that therefore the steam turbine driven vessel was not the last word in efficiency, although in many respects the turbine possessed advantages over the reciprocating engine.

An account was given of the author's investigation of the problem of devising some system of propulsion in which the defects of steam turbine would be wanting, and the resulting introduction of the method of electrical propulsion known as the "Paragon" system, which is now being installed on the collier "Jupiter" of the U.S. Navy. This vessel, of 20,000 tons displacement and about 6,000 h.p., was the first high-power electrically propelled ship ever built, and when her trials are completed an instructive comparison will be possible with her sister ship, the "Cyclops," in which the propellers are driven by steam engines.

The "Paragon" system of electrical propulsion was described in detail and it was shown that this method met all the requirements which had been laid down as necessary for an efficient motive force for driving ships' propellers. It was pointed out that the electrically driven ship had now become a matter of more than academic interest, and that the success which might attend the trials of the "Jupiter" might even change the naval programme of more than one of the Great Powers. An appendix to the paper gave illustrations and descriptions of the system designed and advocated by the author.

Danish Locomotive Building.—In consequence of a general desire throughout Denmark that the country should as far as possible be independent of foreign-made machinery, pressure has been put upon Parliament to encourage the construction of locomotives at home instead of importing them from foreign countries. The result is that the Danish State Railways Administration, which previously ordered its locomotives from abroad, has just ordered three from the Frichs Company at Aarhus. These engines will be of a small type, for shunting purposes, but the company have arranged to build new large locomotive works with the object of constructing not only large locomotives, but also many other kinds of railway material.

IGNITION OF GAS BY MINIATURE ELECTRIC LAMPS.

THE question has often been asked whether firedamp can be ignited by breaking the bulb of a miniature incandescent lamp in a body of it. This question is of more importance now than at any previous time because of the increasing use of electric lamps. The development of the tungsten filament has given a fresh impetus to the manufacture of such lamps.

In connection with its investigations of mine accidents and the dangers attending the use of electricity underground, the American Bureau of Mines, at its experiment station in Pittsburg, has undertaken the study of various matters relating to the ignition of firedamp by electrical equipment. The tests described below were preliminary to more extensive tests which the Bureau proposes to make upon complete portable lamp equipments. The following brief review of the test results is published in advance of a more detailed description of the investigation.

The tests were made with miniature incandescent-lamp bulbs containing tungsten filaments. The bulbs were supplied by the General Electric Company, the Federal Miniature Lamp Company, and the National Electric Lamp Association. In all tests the filaments were glowing at the moment when the bulbs were broken. One hundred and thirty-one bulbs were broken in a mixture of natural gas (that used in Pittsburg) and air combined in the proportion of 8·6 per cent. to 91·4 per cent. air. These percentages of the gas and air form the most explosive mixture.

Forty-five tests were made in gas-and-air mixtures other than the most explosive. These mixtures contained from 3 per cent. to 12·4 per cent. of gas. Mixtures containing as little as 5 per cent. of gas and others containing as much as 12·4 per cent. of gas were ignited by 1·5-candle power, 3·5-volt, 0·3-ampere bulbs that were smashed while burning at rated voltage.

RESULTS OF TESTS.

TABLE I.—*Bulbs causing Ignition at or below Rated Voltage.*

Manufacturer's rating.			Number of tests.	Number of ignitions.	Percentage of rated voltage causing ignition.
C.P.	Volts.	Amperes.			
1·0	2·5	0·3	11	7	100·0
1·5	3·5	0·3	23	16	100·0
2·0	5·5	0·3	9	6	98·7
1·0	2·0	—	9	7	100·0
1·0	2·5	—	10	3	100·0
2·0	4·0	—	10	7	82·2
2·0	4·5	—	10	7	85·3
—	2·0	0·73	5	3	94·5
—	4·0	0·53	5	5	94·9
—	6·0	0·30	5	5	88·2

TABLE II.—*Bulbs causing Ignition at more than Rated Voltage.*

Manufacturer's rating.			Number of tests.	Number of ignitions.	Percentage of rated voltage causing ignition.
C.P.	Volts.	Amperes.			
0·5	1·5	0·4	10	1	132·7
—	2·0	0·23	9	3	120·0
—	2·0	0·40	9	3	106·0
—	2·0	0·53	6	5	102·0

The values given in the last column in each table are the average percentages of the voltages impressed upon such bulbs as caused ignition.

Palmer Engineering Scholarship.—The council of the Institution of Civil Engineers are prepared to consider applications made before December 1st for a nomination to the Palmer Scholarship. The nominee must be the son of a civil engineer; he must be desirous of studying and graduating at the University of Cambridge; and his circumstances must be such as to need the help afforded by the scholarship. It is of the annual value of £40. Copies of the regulations may be had on application to the secretary of the Institution of Civil Engineers, Great George Street, Westminster, S.W.

HEAVY OIL ENGINES.*

BY CAPT. H. RIALL SANKEY, R.E. (RETIRED), M.INST.C.E.

(*Continued from page 542.*)

Various Types and Sizes of Diesel Engines.—There are a very large number of makers of Diesel engines, especially on the Continent of Europe; but so far in this country for land purposes there are only two makers of repute, and the largest engine made by them is about 600 b.h.p. A large majority of the engines manufactured are of the vertical type, and there is a great similarity in all the designs. There is not the same variety that is to be found amongst steam engines, and the reason is two-fold; the designs have emanated practically from one source, and the differences caused in steam engines by variations in steam pressure, and whether the engine is condensing or non-condensing, do not occur. The differences consist principally in the methods of driving the cam shaft and the compressor, and in details of valve levers, fuel pumps and governors.

TABLE II.—*Sizes manufactured by Burmeister & Wain, Ltd.*

B.H.P. One Cylinder ..	30	40	50	60	75	(100)	(125)	(150)	(175)	(200)	(250)
Two Cylinders	-	80	100	120	150	200	250	—	-	-	
Three ,,	—	—	150	180	225	300	375	450	525	600	750
Four ,,		—	200	240	300	400	500	600	700	800	1000
R.P.M.	250	240	225	210	200	190	180	170	160	150	150

Figs. 23, 24, and 25 show views of a reversible 4-line 2-stroke 400 b.h.p. engine (Messrs. Sulzer) in which the scavenging blower and 2-stage air compressor are driven direct by the crank shaft.

Many makers publish lists of sizes up to 1,000 b.h.p. Table II., based on Messrs. Burmeister and Wain's list, gives an example of how, with 11 sizes of cylinders, 24 engines can be constructed varying in power from 30 b.h.p. to 1,000 b.h.p., and in speed from 250 revs. per minute to 150 revs. per minute. With the A frame form of construction the unit consists not only of the cylinder, but also of the valves, connecting rod, and A frame itself, so that by varying the bedplate, the shaft and the two-to-one shaft, several different sizes of engines can be built. This is an important advantage from the manufacturing point of view. A similar table (Table III.) has been prepared from the list published by the Maschinenfabrik Augsburg-Nürnberg Company. In this list there are 17 sizes of cylinders, from which 45 different sizes of engines are constructed. Only a few of the cylinders are shown in the table to indicate the principle. For each size of cylinder the width and height of the engine is the same, but the length varies according to the number of cylinders. This table refers to slow-speed engines; for high-speed engines a similar table could be prepared.

TABLE III.—*Abstract from Table of Sizes manufactured by the Maschinenfabrik Augsburg-Nurnberg Co.*

Number of Lines.	B.H.P. produced at full load at speeds given below.				
One	8*	18	50	150	(250)
Two	—	36*	100*	300	--
Three	—	—	150	450*	750
Four	—	—	200	600	1000*
Revolutions per minute ..	270	250	195	167	150
Overall dimensions -					
	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.
Width	6 7	8 6	11 2	13 9	16 5
Height....................	6 2	7 3	9 10	14 9	16 5
Length (of engines marked thus*) including fly-wheel.	4 5	8 2	10 10	22 4	31 2

Beyond these powers there do not appear to be any standard sizes, but many makers are now prepared to make engines up to 2,000 h.p. and 4,000 h.p. each, and Messrs. Sulzer state that they are prepared to make engines up to 8,000 h.p. running at 105 revs. per minute. According to Dr. Diesel, the 4-stroke cycle engine may at present be regarded as the type for stationary plants from 5 h.p. up to

* Howard lectures delivered before the Royal Society of Arts April May, 1912. Reproduced from the "Journal of the Royal Society of Arts."

800 h.p. It is possible, however, that this position may be affected by improvements in the 2-stroke engine. For torpedo boats and submarines, a light type of engine has been constructed in which the framing is made of manganese bronze, and such things as doors, &c., of aluminium. The weight of these engines is as low as from 40lbs. to 54lbs. per brake horse-power, and with six cylinders they give 150 b.h.p. at 550 revs. per minute. Larger engines with eight cylinders run at 400 revs. per minute and give 1,200 b.h.p.

High-speed engines are made in two types, heavy and light, the former weighing about 110lbs. per brake horse-power, principally for driving dynamos direct, and the latter weighing from 30lbs. to 60lbs. per brake horse-power for destroyers and submarines. The following are examples:—

B.H.P.	No. of Lines.	Revolutions per minute.	
		Heavy.	Light.
150	6	300—400	550
600	6	225—275	450
1,200	8	215	400

Fuel Oils. — The heavy oil engine of the explosion type is much limited in respect of the kind of oil it can use, and great care has to be exercised in its selection. To obtain the best results the compression must be carefully adjusted, and a change in oil usually requires a change in the compression, for which purpose distance pieces are provided for altering the length of the connecting rod. With the Diesel engine almost any kind of oil can be used, even animal and vegetable; for some of them, however, special arrangements are required, though, generally speaking, no alteration in the compression is needed.

A good deal of confusion exists because some of the oils have different names in the various countries; for example, what we call paraffin oil is called petrol in France, and what we call petrol is called benzine in France. In this country it is not unusual to say that "crude" oil is used with the Diesel engine. "Crude" oil, however, is in reality the natural oil as it comes from the earth, and it contains many oils which are too valuable to burn in a Diesel engine; for example, the benzines and petrols, the illuminating oils, which are also used for the ordinary oil engine, and it is only the residue — known, for example, as "Masut" or "Astaki" —which is generally used in the Diesel engine.

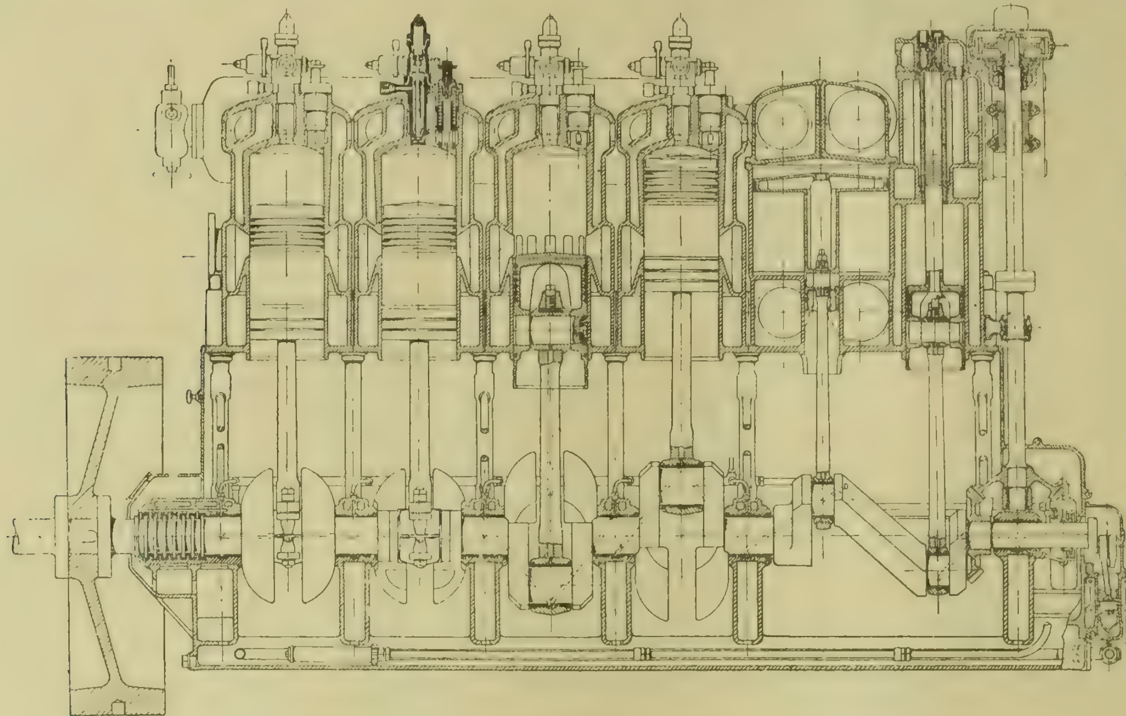


FIG. 23.

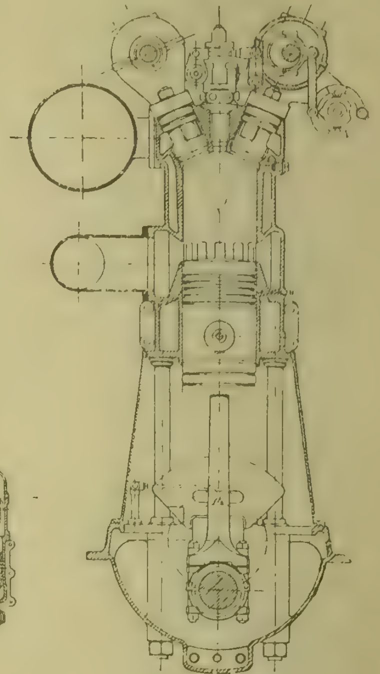


FIG. 25.

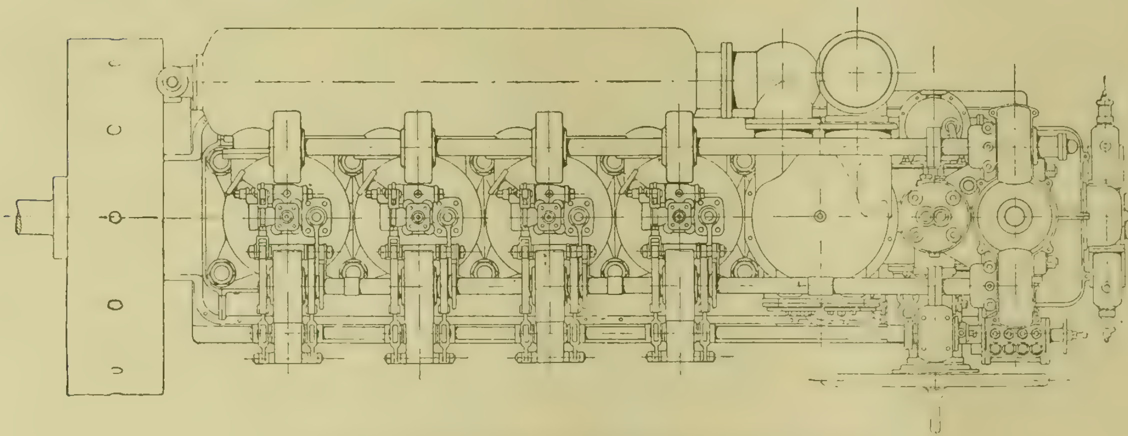


FIG. 24.—SULZER REVERSIBLE TWO-STROKE 400 B.H.P. OIL ENGINE.

The characteristics of a fuel oil suitable for Diesel engines are the following: Chemical composition, viscosity, specific gravity, igniting point, amount of residue, calorific value.

As regards chemical composition, these oils being as a rule hydrocarbons consist principally of carbon and hydrogen. In the crude petroleum the proportion by weight of carbon varies from 82 per cent. to 86 per cent., and that of the hydrogen from 11 per cent. to 14 per cent. In the coal-tar oils the proportion of carbon is about 90 per cent., and that of the hydrogen about 8 per cent. The proportion of hydrogen is important, because on it depends the capability of giving off inflammable gas to initiate the ignition even at the high temperature existing in the Diesel engine at the end of compression. If the hydrogen proportion is insufficient, as in the case of coal-tar oils, special ignition oil has to be used to initiate the combustion. Sulphur is an impurity, and must not exceed $1\frac{1}{2}$ per cent.

Viscosity is not of great importance, because if it is high and the oil will not flow readily, it can be reduced to the desired point by warming the oil by the exhaust gases or by adding, say, 5 per cent. of illuminating oil.

The specific gravity is of no consequence *per se*, but is a reliable guide as to the type of oil under consideration. If the

flash-point is too low danger may arise in storage, especially on board ship. Lloyd's rule is that the flash-point should not be less than 150° Fah. The flash-point of heavy oils, however, is over 350° Fah., and the lower flash-point can only be caused by the admixture of more volatile oils.

If the ignition point is too high, caused, as pointed out above, by insufficient hydrogen, a difficulty will arise with the usually adopted compressions of from 450lbs. to 500lbs. per square inch. Successful trials have been made with oils having a high ignition point by forcing up the compression to 40 atmospheres, that is, about 600lbs. per square inch; but, practically, the difficulty is got over by the use of igniting oil, which will be referred to more in detail later.

The residue should be small, to prevent accumulation on the valves, and so obviate too frequent cleaning of them.

As regards the calorific value, it is important to discriminate between what are known as the higher and lower values, the difference between them being the latent heat of the water produced by the combustion. This latent heat cannot possibly be utilised by an internal-combustion engine, or by a steam boiler for that matter, and two committees of the Institution of Civil Engineers, viz., the Committee on Tabulating the Results of Steam Engine and Boiler Trials, and the Committee on Standards of Thermal Efficiency of Internal-combustion Engines, decided that the lower calorific value should be used for all calculations of thermal efficiency. The higher calorific value is that obtained in a bomb calorimeter, and if the proportion of hydrogen is known it is easy to determine the lower value, because the difference between the higher and lower values for hydrogen is 10,305 B.Th.U. per pound, and hence the following rule can be established: Lower calorific value = higher calorific value − 10,305 × H per cent. Table IV. gives the calorific value, higher and lower, for several types of oils, &c.

In this country petroleum oils, the largest supplies of which come from the U.S.A. and Russia, are used for oil engines. The crude or natural oil contains: (1) Light oils (spirit), specific gravity 0·65 to 0·76, which are used for petrol engines; (2) medium oils, specific gravity 0·76 to 0·86, used for illuminating and for explosion engines; (3) lubricating oils; (4) residues, from which fuel oils for Diesel engines, specific gravity 0·86 to 0·94, are obtained, together with solids such as paraffin wax and pitch.

In 1899 the oil production of the U.S.A. was about ten million tons, and that of all other countries also ten million tons. In 1910 the oil production of the U.S.A. had gone up to twenty-four million tons, and that of other countries to eighteen million tons.

TABLE IV.

Description of Oil.	Specific Gravity.	Hydrogen Content. Per cent.	Calorific Value, B.Th.U. per lb. Higher.	Lower.
Petrol — Bowley's Special	0·684	—	—	19,190
Petrol — Pratt	0·719	—	—	18,610
Petrol — Shell	0·767	—	—	18,250
Russolene	0·82	14·0	19,820	18,380
Gas Oil (from brown coal)	0·825	12·3	17,900	16,630
Average "Fuel Oil"	0·89	—	—	18,000
Masut	0·90	13·9	18,600	17,170
Baku Residue	0·928	11·7	11,200	10,000
Coal-Tar Oil (creosote and autracene)	1 to 1·1	6·6	15,800	15,120

In Germany, owing to the high duty on residue oils—36s. per ton—coal-tar oils are principally used with the Diesel engine. Originally the Diesel engine could only use oils having the relatively high proportion of 11 per cent. to 14 per cent. of hydrogen, which excluded tar oils, as they only contain 6 per cent. to 7 per cent. of hydrogen; the reason being that with the usual compression of from 30 to 32 atmospheres, the temperature reached is insufficient for ignition. It has been found possible to use tar oils by increasing the compression to over 40 atmospheres, but as a practical matter it has been found better to retain the usual compression, and to effect the ignition by a pre-injection of ignition oil, which usually is the oil employed for making oil gas. From 3 per cent. to 5 per cent. of the ignition oil at full load is required, and the heat produced by the burning of this oil raises the temperature to the point required for the ignition of the tar oil.



FIG. 26.—THE WORLD'S OUTPUT OF OIL FROM 1857 TO 1910.

The Maschinenfabrik Augsburg-Nürnberg Company used a closed nipple. The ignition oil is injected by a separate pump, and the practice is to use a constant amount for all loads; that is to say, the amount of ignition oil is not regulated by the governor, and only the tar oil pump supply is thus controlled. In the Körting engine the governor controls both the ignition oil and the tar oil.

The tar oil must be screened to remove solid impurities, and the water must be eliminated. This latter is a difficult matter with tar oils obtained from horizontal or inclined retorts, but the water separates easily from the oil obtained from vertical retorts. The tar oil must be pre-warmed, say by the exhaust gases, in order to render it fluid, but the temperature must not be sufficient to cause any distillation. Animal and vegetable oils can also be used in the Diesel engine, and the matter is now receiving much attention from Dr. Diesel.

A fuel-testing laboratory has been established at the University of Zurich under the direction of Prof. Constan, and it is probable that a similar laboratory may be established in this country.

From tests and examinations already made, power oils have been divided into the following three classes:—*

(1) Normal oils which can always be used:—

(*a*) Mineral oils freed from benzine (gas oils) ...	Hydrogen over 10 per cent. Calorific power over 10,000 cal. (39,680 B.Th.U.)† No solid impurities.

† Higher calorific value per kilogramme.

(*b*) Lignite tar oils... ...	Hydrogen over 10 per cent. Calorific power over 9,700 cal. (38,489 B.Th.U.).
(*c*) Fat oils from vegetable or animal sources, such as earthnut oil, castor oil, fish oils, &c. ...	Scarcely any researches have been made on these. Earthnut oil has 11·8 per cent. hydrogen, and calorific power 8,600 cal. (34,124 B.Th.U.)

(2) Oils which can be used only with the aid of special apparatus: (*a*) Pit coal-tar oil; (*b*) vertical-oven, water-gas, and oil-gas tars, probably also coke-oven tars, the tests on which have not yet been completed.

General characteristics: Hydrogen not over 3 per cent.; amount of free carbon not over 3 per cent.; residue on coking not over 3 per cent.; calorific power not under 8,600 cal. (34,124 B.Th.U.).

(3) Oils which cannot be used: Tars from horizontal or inclined retorts.

It must not be understood that these will not be used in Diesel engines under special conditions; but, on the whole, the above classification is accurate in the present state of development of the Diesel engine.

Specifications of Tar Oil Suitable for Diesel Engines.‡—(1) Tar oils should not contain more than a trace of constituents insoluble in xylol. The test on this is performed as follows: 25 grammes (0·88 oz. av.) of oil are mixed with 25 cm. (1·525 cub. in.) of xylol, shaken and filtered. The filter paper before being used is dried and weighed, and after filtration has taken place it is thoroughly washed with hot xylol. After redrying, the weight should not be increased by more than 0·1 gr.

(2) The water contents should not exceed 1 per cent. The testing of the water contents is made by the well-known xylol method.

(3) The residue of the coke should not exceed 3 per cent.

(4) When performing the boiling analysis, at least 60 per cent. by volume of the oil should be distilled on heating up to 300° C. The boiling and analysis should be carried out according to the rules laid down by the Trust.

(5) The minimum calorific power must not be less than 8,800 cal. per kilogramme. For oils of less calorific power the purchaser has the right of deducting 2 per cent. of the net price of the delivered oil for each 100 cal. below this minimum.

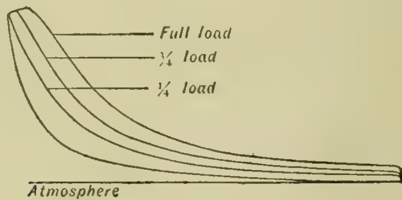


FIG. 27.

(6) The flash-point, as determined in an open crucible by Von Holde's method for lubricating oils, must not be below 65° C.

(7) The oil must be quite fluid at 15° C. The purchaser has not the right to reject oils on the ground that emulsions appear after five minutes' stirring when the oil is cooled to 8°.

Purchasers should be urged to fit their oil-storing tanks and oil pipes with warming arrangements to redissolve emulsions caused by the temperature falling below 15° C.

(8) If emulsions have been caused by the cooling of the oils in the tank during transport, the purchaser must redissolve them by means of this apparatus.

Insoluble residues may be deducted from the weight of oil supplied.

Fig. 26 shows the world's output of oil from 1857 to 1910 expressed in millions of tons.

Testing of Oil Engines.—The testing of Diesel and oil engines is comparatively easy, at anyrate so far as measurements of the fuel are concerned, and in this respect presents a great contrast to the difficulties arising in testing steam engines and boilers, or gas engines and producers. The simplest method of weighing oil is to fit the tank supplying the oil to the fuel valve with a pointed hook gauge. Assuming the level of the oil to be above the point of the gauge, as this level sinks a moment will arrive when the point of the gauge will emerge from this surface, and can be snapped on a stop watch. Later, a weighed quantity of oil is emptied into the tank sufficient in amount again to cover the point of the hook gauge. The moment at which the point again issues is taken on the stop watch, and the interval thus recorded is obviously the time needed to consume the weighed amount of oil; this process can be continued as long as desired, and if the load on the engine is constant and the same weight of oil is emptied into the tank each time, the time intervals ought to be substantially the same. As regards measurement of power, the engine can either be made to drive a calibrated dynamo, in which case the kilowatts are measured, or a brake is used, usually of the hydraulic type.

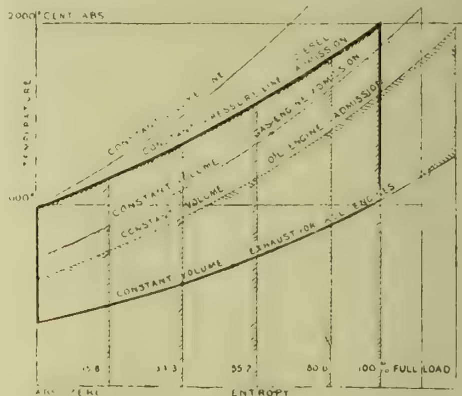


FIG. 28.

Fuel Economy at Various Loads.—Fig. 27 shows indicator diagrams taken at varying loads. It will be noticed that the compression is constant, and that the area of the diagram is reduced by reducing the approximately constant pressure part of the diagram, which means that less fuel is used, and that the time of combustion is shortened. The action is similar to altering the cut-off of a steam engine. In this case the revolutions remain constant, which is the usual condition for land engines. In the case of marine engines, however, the load is reduced by diminishing the number of revolutions; in this case the oil consumption per diagram remains approximately what it is at full load, and the brake efficiency also remains nearly constant instead of diminishing as it does when the revolutions remain constant. The effect is that the oil consumption per brake horse-power is more nearly constant at all loads than it is in the case of constant revolution engines. The following published results illustrate this point:—

B.H.P.	lb. per B.H.P. hour.	
	Chalkley.	Sulzer.
400	0·473	0·471
300	0·475	0·471
200	0·496	0·477
100	0·493	0·546

The above results are those obtained on test, but it would appear that they are substantially maintained in actual work. A special advantage of the Diesel engine is that it only consumes fuel when actually running, and it is able to start

* From Dr. Diesel's paper read before the Institution of Mechanical Engineers, March 15th, 1912.

‡ From the German Tar Production Trust at Essen-Ruhr.

immediately and stop immediately; this latter advantage is not shared by any other prime heat mover except petrol engines. In the case of the steam engine the steam has to be got up in the boiler, and when the engine is shut down there is still a large amount of unutilised heat in the unburned coal on the grate, in the heat in the boiler setting, in the water in the boiler, &c. With a gas engine time is required before the producer can make gas, and when the engine is shut down a considerable amount of

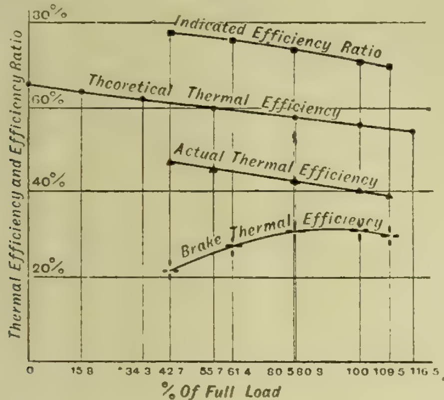


FIG. 29.

fuel is left in the producer. In the case of other heavy oil engines the hot bulb has to be heated by means of a lamp; there is, however, no fuel wasted on stopping the engine.

In Fig. 6 (see page 476 ante), which referred to the case of a 4-stroke engine, the brake thermal efficiency was given as 31·0 per cent., and assuming the calorific value of the fuel to be 18,500 B.Th.U. per pound, the heat converted into work on the shaft will be $18{,}500 \times 0{\cdot}319 = 5{,}740$ B.Th.U. per pound of oil consumed. Hence the consumption of oil per brake horse-power at full load would be $2{,}545 \div 5{,}740 = 0{\cdot}443$lb.

In the case of the 2-stroke engine the brake thermal efficiency would be reduced to 29·7 per cent., and the oil consumption increased to 0·461b. per brake horse-power.

The above figures relate to the full-rated load of the engine as given in price lists, and the makers generally guarantee a 10 per cent. overload for, say, two hours, but with a slightly increased consumption. As the load diminishes the oil consumption per brake horse-power increases. The following is a typical guarantee, expressed in pounds of oil per brake horse-power (calorific value 18,500):—

Quarter.	Half.	Three-quarter.	Full.	10 per cent. Overload.
0·64	0·50	0·45	0·448	0·458

Considerably better results than these are obtained. Those given in Table VI., published by the Maschinenfabrik Augsburg-Nürnberg Company (converted to English units and English horse-power) appear to be about the best.

The consumption of Diesel oil engines is always quoted per brake horse-power, and this is as it should be in respect of the user; but from the scientific point of view it is desirable to know what the consumption is per indicated horse-power. In this connection it is to be observed that the area of the indicator diagram in the case of the Diesel engine represents a power greater than the true indicated power which is defined as the power produced in the cylinder by the combustion of the fuel. In the case of the Diesel engine a certain amount of the power required for compressing the pulverising air is recovered in the cylinder by admission of the high-pressure air. To give an idea of the effect of this recovery of power, let it be assumed that the oil consumption is 0·45lb. per brake horse-power hour, and that the ratio of the brake horse-power to indicated horse-power shown by the actual indicator card or "card I.H.P." is 76 per cent.; then the oil per "card I.H.P." will be $0{\cdot}45 \times 0{\cdot}76 = 0{\cdot}342$. It may also be assumed that the power shown by the indicator cards of the air compressor is 7 per cent. of that shown by the indicator card of the engine cylinder, and if 5 per cent. is recovered—that is to say, if the indicator card is reduced by 5 per cent.—then the oil consumption per true indicated horse-power will be increased to $0{\cdot}342 \times 1{\cdot}05 = 0{\cdot}359$.

Mr. Dugald Clerk thinks that the whole 7 per cent. should be deducted, in which case the oil consumption per true indicated horse-power would be increased to 0·366. The subject is somewhat difficult, and has not yet been fully considered.

The figures given above refer to full load, and corresponding figures for other loads are given in Table VII. It will be noticed that the oil consumption per indicated horse-power diminishes as the load gets less.

TABLE VII.

	Quarter load.	Half load.	Three-quarter load.	Full load.	10 per cent. over load.
Per B.H.P.	0·64	0·50	0·45	0·448	0·458
Card I.H.P.	0·29	0·51	0·32	0·342	0·354
True I.H.P.	0·305	0·325	0·336	0·359	0·372

The following comparison* of a slow-speed and a high-

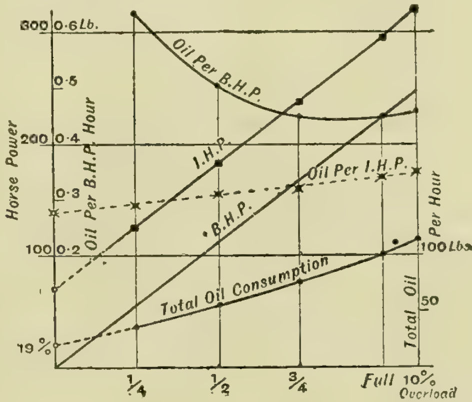


FIG. 30.

speed Diesel engine of 250 b.h.p. to 300 b.h.p., driving a dynamo, will be of interest. Both engines were of 4-stroke type, single-acting. They had a 2-stage vertical air compressor, compressing from atmosphere up to 50 atmospheres to 70 atmospheres, and driven by an overhanging crank. The speed could be altered from 400 revs. per minute to 150 revs. per minute, the engines being intended for ship driving.

* Lee.

TABLE VI.

Where Running.	Size. B.H.P.	Oil used and Calorific Value, B.Th.U., per lb.	Load.	Oil Consumption. Lb. per B.H.P. hour.	Thermal Efficiency per B.H.P. per cent.	By whom Tested.
Manufacturing Co., J. L. Skworzow, Sereda, Russia.	800	Galician Gas Oil, 18,060.	4/4	·366	38·4	Consulting Engineers, Perelmann and Heally, Moscow.
	4		3/4	·375	37·5	
	Cylinders.		1/2	·414	34·0	
Parma, Officina Elettrica Comunale.	500	Gas Oil and Masut mixed, 18,000.	5/4	·390	36·2	Testing Commission (Professor Ferraris, Engineers, Dainoni and Carpani).
	4		4/4	·379	37·3	
	Cylinders.		3/4	·405	34·9	

Description.	High speed.	Low speed.
Length	3,655 mm.	4,275 mm.
Width	1,060 ,,	2,000 ,,
Height	2,120 ,,	3,375 ,,
Weight without flywheel	11,800 kg.	22,900 kg.
Cost	15 per cent. to 20 per cent less than low speed.	
Oil consumption (grammes per B.H.P.)		
Overload	205	205
Full load	195	195
Three-quarter load	215	215
Half load	235	240

At full load the brake efficiency in both cases was 0·78. These engines were worked with the following oils: Crude naphtha of 0·88 sp gr.; solar oil of 0·883 sp. gr.; a mixture of 70 per cent. solar oil and 30 per cent. masut 0·88 sp. gr., and with masut 0·9 sp. gr.

It will be interesting to determine what the oil consumption ought to be from theoretical considerations, and it is proposed to do this by means of the heat chart, Fig. 4 (see p. 475 ante). In Fig. 28 is shown the heat chart diagram of a Diesel engine, and, for comparison, that of a gas engine, and also of an explosion heavy oil engine. In the case of the two latter, as already explained, the admission of heat theoretically takes place at constant volume, and the abstraction of heat also takes place at constant volume. Assuming constant specific heat, it can be shown that each element of the heat introduced has the same thermal efficiency. Actually, however, the specific heat increases with temperature, and the constant volume lines shown in Fig. 28 have been drawn taking account of the increase of specific heat according to the figures given by Mr. Dugald Clerk in his paper for the Institution of Civil Engineers. The effect of this increase of specific heat is to make the slope of the constant volume line for admission less than that for the exhaust, and, consequently, the thermal efficiency of elements of heat added at the higher temperatures is less than that of those added at the lower temperatures. This effect, however, is greatly increased in the case of the Diesel engine, as will be obvious from the figure by comparing the constant volume and constant pressure lines drawn through the initial point of combustion.

In the case of the Diesel engine, the power is reduced by diminishing the oil supply, and on the diagram this is expressed by reducing the area, which corresponds to the amount of heat produced per stroke at full load. Four cases have been taken in Fig. 28, and the percentage of full load is indicated in the left-hand bottom corner of each area. From these the theoretical indicated thermal efficiency for each of these loads can be obtained by measuring the respective areas; this has been done, and the result is given in Fig. 29, and it will be seen that all the points lie sensibly in a straight line, and that the thermal efficiency at no load is 65 per cent. and at 10 per cent. overload it is reduced to 55 per cent.

Results of tests made by the lecturer on a 3-throw 225 b.h.p. engine at Messrs. Willans & Robinson's works in 1909 have also been inserted in this figure. It will be seen that the actual thermal efficiency per indicated horse-power at the various loads tested also lies very nearly in a straight line. The ratio between the actual thermal efficiency and the theoretical thermal efficiency gives the efficiency ratio, and this has also been plotted on the figure, and it will be seen that the efficiency ratio is greater at light loads than it is at full load within the limits of the test, as might be expected, because within these limits the combustion will probably be equally good, and as the temperatures at light loads are less than at full load there will be less loss, and therefore better efficiency ratio. At heavier loads and at much lighter loads the combustion may become more imperfect and the efficiency ratio will then be reduced.

Returning to Fig. 29, the reason for the lesser thermal efficiency of the gas engine and of the ordinary oil engine is obvious; in the cases given, at full load the theoretical thermal efficiencies are, respectively: Diesel oil engine, 57 per cent.; gas engine, 51 per cent.; explosion oil engine, 41 per cent.

In Fig. 29 the brake thermal efficiency is also shown, deduced from the experiments for the tests referred to above. The power required for driving the engine was found to be sensibly 69 h.p., and the effect on economy is clearly shown by the curvature of the brake efficiency line. At full load the best figure is obtained; at light loads the improvement in indicated thermal efficiency is overshadowed by the loss due to the brake loss; and above full load, although the brake efficiency is better, the brake thermal efficiency is less because of the reduced indicated thermal efficiency.

The total fuel used per brake horse-power is plotted in Fig. 30 on a load base, and it will be seen that it nearly follows a Willans line, which if produced cuts the origin at a point showing an oil consumption of 19 per cent. of the full load fuel; that is to say, that the engine, when running light, requires 19 per cent. of the full load fuel. On producing the line showing fuel consumption per indicated horse-power, it is found that 0·28lb. of oil is required per indicated horse-power, and as the brake loss is 69 h.p., the oil consumption works out to $0·28 \times 69 = 19·3$lbs., which is 19·3 per cent. of the total fuel per hour, namely, 100lbs., and, therefore in good agreement with the figure previously obtained.

TABLE VIII.

Description of Engine.	Percentage difference between I.H.P. and B.H.P.					
	Size. B.H.P.	Quarter load.	Half load.	Three-quarter load.	Full load.	10 per cent. Overload.
Sulzer, vertical 2-stroke, 136 revs. per minute	1000	36·0	36·4	37·0	39·0	—
Carels, vertical 2-stroke, 200 revs. per minute	1000	37·5	37·7	40·4	43·0	—
M.A.N., horizontal 2-stroke, 150 revs. per minute	1000	30·6	30·6	30·7	30·0	—
Krupp, vertical 2-stroke, 150 revs. per minute	1000		33·4	37·0	35·0	—
Burmeister & Wain, vertical 4-stroke, 150 revs. per minute	1000	25·0	26·2	26·3	26·6	—
Willans & Robinson, vertical 4-stroke, 200 revs. per minute	225	30·8	30·6	30·6	30·7	31·2

The indicated horse-power and brake horse-power lines are also plotted on Fig. 30, and it will be seen that these lines are sensibly parallel, that is, the power required to drive the engine and the air compressor was 69 h.p. at all loads, and since the full load is 225 b.h.p. the percentage is 30·7. The approximate constancy of the difference between the indicated horse-power and the brake horse-power appears to be general with Diesel engines, as is shown by Table VIII., deduced from actual guarantees, the percentage varying, however, with the size of the engine, whether vertical or horizontal, and whether of the 4-stroke or 2-stroke type.

(*To be continued.*)

Clyde Shipbuilding Output.—The Clyde shipbuilding output during October has been on a substantial scale, totalling 48,045 tons, spread over 19 vessels. The aggregate for the ten months of the year is thus raised to 520,318 tons, which is 10,500 tons above the previous record for the corresponding period established in 1906. In only two previous Octobers has this month's total been exceeded. The new work booked includes four armoured cruisers for the British Admiralty.

New Electric Plant for Manchester.—The Manchester Corporation Electricity Committee have accepted the tender of Messrs. James Howden & Co., Ltd., of Glasgow, for a new 15,000 kw. unit, with Messrs. Siemens as sub-contractors for the alternator, and Messrs. Richardsons, Westgarth, for the condensing plant. The main turbine will be of the Howden Zoelly pure impulse type, with 14 wheels, designed to work with a steam pressure of 200lbs., superheat 200° Fah., and vacuum 27½in. The speed will be 1,000 revs. per minute. The main alternator will be of the totally enclosed type. The rotor will be of the solid type, cylindrically wound. The main condenser will be of the Contraflo design, and the circulating pumps will be of the Rateau type and in duplicate, both sets being driven by steam turbine. The kinetic air pumps and water pumps are also in duplicate, and each line is to be driven by an auxiliary steam turbine. The turbine and alternator weigh 250 tons, and, including the condensing plant, the total weight will be approximately 350 tons.

DAVIDSON & LARMUTH'S INTERNAL-COMBUSTION ENGINE.

We illustrate herewith a design of 2-stroke cycle internal-combustion engine of the type in which two cylinders placed side by side are in open communication with each other at

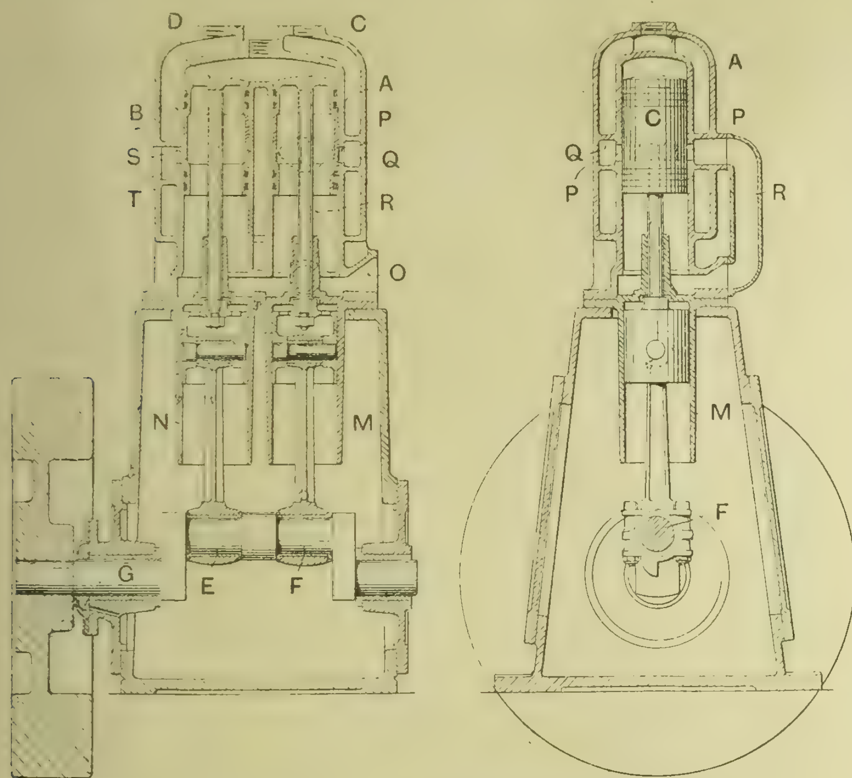


Fig. 1.—Davidson & Larmuth's Internal-combustion Engine.

both ends, one of the cylinders having inlet and the other exhaust ports controlled directly by the pistons in the cylinders, and the combustible mixture being compressed in the crank chamber before entering the cylinders—the joint invention of Mr. John Davidson, of 39, Devonshire Road, Pendleton, Manchester, and Mr. William O. Larmuth.

Referring to Fig. 1, the working cylinders A, B are in direct communication with one another at both ends and are water-jacketed. The outer end of the cylinder A has an inlet O connected with the combustion charge supply and furnished with a non-return valve (not shown). The cylinder A has inlet ports P around it in or about the middle, which are connected together by a belt Q, and by means of a pipe R brought into communication with the outer ends of the cylinders A and B. The cylinder B has around it also in or about the middle exhaust ports S, which are connected together by a belt T furnished with an exhaust pipe (not shown).

The cycle of operations is as follows: Upon the up-stroke of the pistons C and D the combustible charge is drawn into the outer ends of the cylinders through the inlet O, while on the down-stroke of the pistons C and D the combustible charge drawn in is somewhat compressed, being prevented from returning by the non-return valve. When the piston D of the cylinder B is nearing the end of its down-stroke, it uncovers the ports S. The pressure of the burnt gases in the cylinders A, B then falls at once, and at the same time the charge inlet ports P in the cylinder A are uncovered by the respective piston. The compressed charge within the outer end of the cylinders A and B then rushes through the pipe R and inlet ports P into the other end of the cylinder B, driving before it the exhaust gases and completely filling both cylinders A and B with a fresh charge; the pistons C and D then rising compress the charge, which is fired when they reach the inner end of their stroke in the usual way. With a view to preventing loss of the incoming charge, through the exhaust ports S, the crank pins E, F are set at slightly different angles, so that the exhaust ports S open somewhat before the inlet ports P, and also close slightly before the latter close. The piston C in the cylinder A may be made much smaller in diameter than the piston D and act as a distributing valve instead of a working piston. It will, however, still operate and tend to assist to turn the crank shaft in the ordinary way.

In the arrangement shown in Fig. 2 the piston-like crossheads K and L are utilised as air compressors for scavenging purposes. The chambers U and V are provided with non-return valves W and X, and a distributing piston valve Y is arranged to be driven from an eccentric or crank Z and work in a casing. The bottom of the casing G is in direct communication with the chamber V, and the top of the same communicates with the outer end of the cylinders A and B by a pipe H. The chamber U is in direct communication with the atmosphere.

This engine operates as follows: When the pistons C and D are forced inwards by the explosion of the combustion mixture, the piston D commences to uncover the exhaust ports S, and thereby relieves the cylinders A and B of excessive pressure before the scavenging air is admitted. The piston C then uncovers the inlet ports P, and as the valve Y is above the port J, it allows the compressed air from the chamber V to enter the cylinder A and drive out the exploded gases from both cylinders A and B. The valve Y then commences to descend with a velocity which increases as the piston nears the end of its inward stroke, until it comes below the port J, and thereby allows the charge compressed in the outer ends of the cylinders A and B by the pistons C and D to pass through the pipe H and port J into the cylinder A and thereby charge both cylinders A

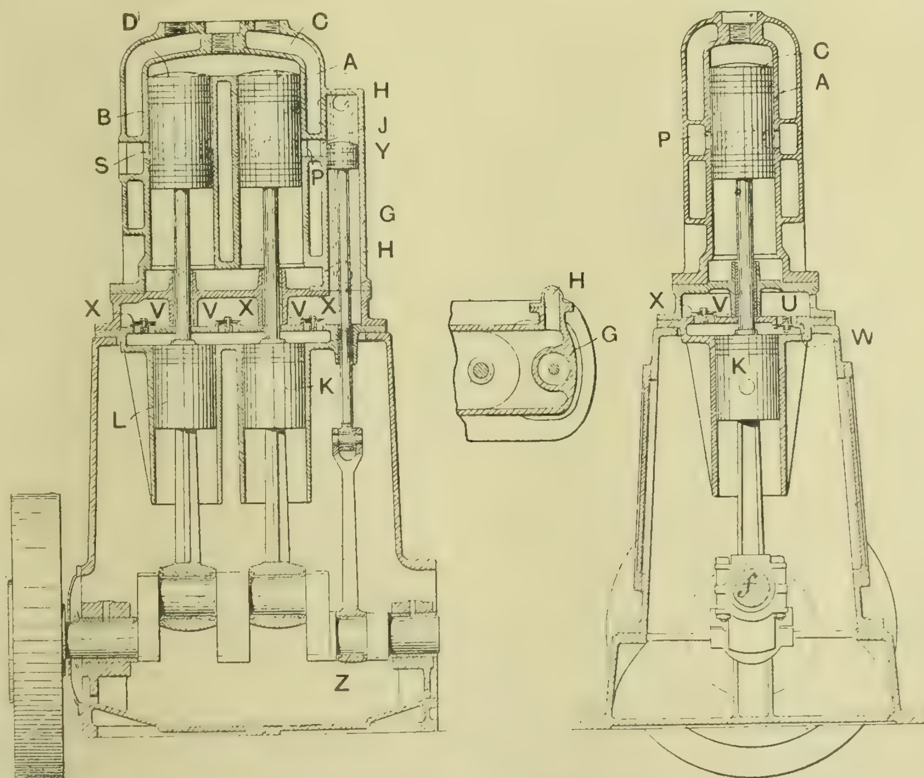


Fig. 2.—Davidson & Larmuth's Internal-combustion Engine.

and B. The port J remains open until covered by the now outward moving piston C, whereupon the new charge is fired and the operation repeats itself. The air is drawn through the chamber A when the pistons move inwards, the valves X closing the chamber V during this time, and then forced into the chamber V in a compressed state during the outward stroke of the piston, the valves W preventing it from returning to the open air through the chamber U. The chamber V thus serves as a reservoir for the compressed air. The engines described may be made to have two, four, or six cylinders, or more according to the power and speed required.

SCIENTIFIC SHOP MANAGEMENT ON THE TAYLOR SYSTEM.

In a paper on the above subject by Mr. G. C. Allingham, read before the Junior Institution of Engineers, the author said it had long been universally recognised that manual labour, generally speaking, was very inefficiently performed, and that the working man, if only he could by some means be induced to do his best, could do a great deal more work, per hour or per day, than he actually did. Many remedies for this state of things had been proposed and tried; and these included premium or bonus systems of payment, profit-sharing or co-partnership of various kinds and philanthropic schemes, but none of these had met with any considerable measure of success. As things were at present, the interests of masters and of men were, he observed, essentially opposed in this respect, that it was the interest of the masters to get as much work as possible out of the men in a given time, while it was the interest of the men to do as little work as possible in the time. There was also always a natural tendency on the part of the worker to jog along at an easy pace, unless there was something to keep him constantly up to the scratch. Another cause of inefficiency was that the men did not know how to do their work in the most efficient way. Employers did not attempt to ascertain in any systematic way what was the most efficient and quickest way to do each job or to give definite instructions to the men how to do it; the man was supposed to "know his trade," to need only to be told what to do, and not exactly how it should be done. Mr. F. W. Taylor, the distinguished American engineer, had, however, shown how this could all be changed. He had shown us how the amount of labour required for any given piece of work could be scientifically ascertained, as accurately as the amount of material. For the past 30 years Mr. Taylor, and those associated with him, had been engaged in a systematic study of manual labour of various kinds, with a view to determining, in a scientific manner, the laws governing the speed with which work of all kinds could be done. As the result of their investigations, they had found that, as a general rule, work could be done, not merely in spurts, but steadily and continuously, in from one-half to one-quarter of the time hitherto expended, and, by applying their methods to practice, they had actually succeeded in doubling, trebling, and even quadrupling the output of the workmen of those firms who had adopted the Taylor System of Scientific Management.

The author said the principle on which Mr. Taylor and his associates had worked throughout their investigations had been to analyse every piece of work into its component elements, and to study and time each element separately. A comparatively simple law could be arrived at governing the time required for each element; but each element was affected by different factors, so that if an attempt were made to study the job as a whole, the number of variables in the equation would be so enormous that it would be hopeless to attempt to solve it. By the determination of a comparatively small number of unit times for any given class of work it became possible to calculate the exact time required for a very large variety of jobs, which were built up of various combinations of those units. The unit times were arrived at by means of "time studies" or by timing the work with a stop watch. A man was selected who would take an interest in the work and would co-operate in the investigation in hand. It was occasionally necessary to time the men without their knowledge; but wherever possible it was best to time them openly and with their consent and co-operation. The man was given an explanation, suited to his capacity, of the object of the time study, and it was made clear to him that it would eventually enable him to earn higher wages. It was then usually found that he was quite willing to help in the work; and, in order to make the man more willing to do his best, he was paid extra money while he was being timed. The work was divided up into elements, and each of these was timed separately. While this was being done, the motions of the man were carefully watched; and if the observer were an expert, who had had considerable experience of study of this kind, he generally found it possible to cut out unnecessary motions and to improve others, and so to expedite the work considerably. Intelligent and close observation of this kind had resulted in many improvements having been made in the methods of carrying out manual work, as well as in the speeding up of machines by the modification of details.

This "motion study," or systematic study of the motions performed by a worker, was in itself a very important branch of the process of increasing the efficiency of labour. The motions of a bricklayer in laying a brick were, for example, reduced from 18 to 5, and, in one case, from 18 to 2, and the number of bricks laid was increased from 1,000 to 3,500 per day, with, if anything, less physical effort to the bricklayer than before. Systematic experiments had been made to ascertain the most efficient method of carrying out various kinds of work. For instance, the art of shovelling had been scientifically investigated. Two or three first-class shovellers were selected, and, for several weeks, their work was carefully observed by trained observers; the shovel load was gradually varied, and it was found that there was a definite shovel load with which a larger tonnage per day could be shovelled than with a load either above or below that amount. A first-class man could do his biggest day's work with a load on his shovel of 21lbs.; with a load of either 24lbs. or 18lbs. he could not do so much. As a result of this, it was found that it paid to use shovels of different sizes for different materials; for instance, the same shovel that would pick up 30lbs. of iron ore would pick up only 4lbs. of small coal, which was not only lighter, but very slippery; it was obvious, therefore, that a smaller shovel should be used for the ore and a much larger one for the coal.

Another instance mentioned by the author was the loading of pigs of iron into railway trucks from stacks on the ground. Instead of allowing the men to work and rest as they felt inclined, they were told when to pick up a pig and walk, and when to stop and rest. And it was found that whereas, when left to their own devices, the men loaded 12½ tons of pig per man per day, when they worked according to instructions, with those intervals of rest which were found by experiment to be best, they could handle 47½ tons per man per day, or very nearly four times as much. This result could never have been attained without time study and training of the men; without training they could not tell how often and how long they ought to rest. If no daily task was fixed, the men rested more than was necessary, they could work more and rest less without overtiring themselves; on the other hand, if the task were fixed at the higher limit and the men were left to reach it as best they could without guidance or direction, they would probably rush at the work and tire themselves out before half the day was done. In all heavy labouring work of this description it had been found that there was a definite percentage of the working day during which the man could be under load without becoming unduly exhausted.

By far the most remarkable of all the instances of scientific investigations of this kind made by Mr. Taylor and his co-workers was that of cutting metals. Experiments were made to determine the laws connecting the cutting speed and feed with the rate at which metal could be removed from the casting or forging. By plotting the results of the various series of tests, curves were obtained, from which mathematical expressions were deduced representing the relations between the different sets of variables. These expressions were found to be logarithmic in character, so that it was possible to construct slide rules, by means of which the very complicated equations which have to be dealt with could be solved without difficulty by any ordinary clerk or foreman. With such a slide rule the best speed and feed for a given job, on a given machine, could be worked out in a fraction of a minute. When the correct cutting speeds and feeds for the jobs in hand were calculated in this way it was frequently found that, in order to obtain them, it was necessary to alter the pulleys on the machines or countershafts, or the feeds of the machines, and, by alterations of this kind, great increases of output were often obtained. In fact, this investigation had shown up the

fact that hitherto the driving and feed gears of machine tools had not been designed on any scientific basis.

Having ascertained how to calculate the cutting speed and feed, the time required to remove a given amount of metal could thus be estimated, and special slide rules had been constructed for this purpose also. When any given machining job had to be done it was divided up into its elements, such as: (*a*) Lifting work from floor to machine; (*b*) putting on carrier; (*c*) adjusting work in chuck or on centres; (*d*) calipering; (*e*) setting tool; (*f*) making cuts; (*g*) extra hand work; (*h*) removing work. In making actual time studies these elements were still further sub-divided.

The principles of scientific time study were summarised by the author briefly, as follows: (1) Each piece of work was analysed into its constituent elements; (2) the minimum time required to carry out each element, *i.e.*, its "unit time," was determined and recorded; (3) records of unit times for a large variety of elements having been accumulated, the time that would be required for carrying out any new job could be predicted with a high degree of accuracy by adding together the already known unit times of the elements of which it was composed. When fixing a standard time for a new job the time required was calculated in this way, and afterwards checked by putting on a first-rate man to do the job and timing him with a stop-watch. A very large quantity of data had already been amassed, as the result of the work of Mr. Taylor and his associates, as to the "unit times" for the elements composing work of a great variety of kinds, and these data were being added to every day.

The author next referred to the advantages to the employer of being able to ascertain how quickly any kind of work could be done. In the first place, the amount of work which each workman ought to do in a day could be defined, and the piecework or premium rates fixed on a definite and accurate basis, giving the men an undertaking that, so long as the method remained unaltered, the rates would never be "cut." The rates were therefore fixed so that, by working fairly, the men were able to earn wages exceeding the ordinary rates by an amount which varied between 30 per cent. and 100 per cent., according to the class of work. When the payment was by time a large fixed bonus was paid, in addition to the ordinary day-wages, if the work was done in standard time or less. This bonus usually amounted to from 20 per cent. to 50 per cent. of the total day-wages, according to the class of work. In order to carry out the system, a special planning department was provided in the works. The time-studies were carried out by the staff of this department, who prepared an "instruction card" for every job which was issued to the workman. On this card all the elements of which the job was made up were set forth in a table, together with the standard "unit-time" allotted to each and the fatigue-allowance. The card specified the tools, jigs, &c., to be used for each operation, and, in the case of machining, it stated where to start each cut, the exact depth of each cut, how many cuts to take, and the speed and feed to be used for each cut. On the card were also entered the numbers of the drawings to be referred to, and, of course, the piece number and order number of the job; the piecework or premium rates to be paid for the job were also stated. The planning department also arranged the exact route by which each piece of work was to travel through the shop from machine to machine, so that it could be done in the most economical manner.

No doubt, when the Taylor system was introduced into this country, the trade unions would not like it at first. The trade unions in this country were more powerful than in the United States, or indeed in almost any other country, except perhaps Australia, and they might put greater difficulties in the way than those experienced in America. But such difficulties would be only temporary; in the end, the trade unions would no more be able to resist the introduction of the Taylor system than they had been able to resist the introduction of labour saving machinery. The system was already in extensive use in the United States and Canada; and at least 50,000 workmen in the United States were employed under it. It had been applied to a large variety of different trades and there appeared to be no reason why it should not be applied with equal success to work of almost every kind. The output per man had been increased three or fourfold, so that, although the earnings per man had been increased by from 30 to 100 per cent., the total labour costs had been reduced to one-half, or less than one-half, of what they were under the old system even in well-managed works. This represented the improvement that had been obtained solely as the result of the introduction of the system of scientific management, the plant and equipment remaining the same as before.

A BIRMINGHAM BOILER EXPLOSION.

THE DANGER OF NEGLECTING INSPECTION.

A BOARD OF TRADE enquiry was held at Birmingham on the 30th ult. into the circumstances attending a boiler explosion which occurred on April 22nd last at the premises of the late firm of Messrs. W. H. Butcher & Co., 30, Princip Street, Birmingham. The Board of Trade Commissioners were Messrs. George Warner, barrister-at-law, and Arthur J. Maginnis, consulting engineer.

Mr. Vaux, solicitor for the Board of Trade, said the boiler was of the ordinary Lancashire type, made of steel in 1896, with a working pressure of 80lbs. to the square inch. It was used by Messrs. Butcher for supplying steam to an engine which drove the beams used in the boring and grinding of gunbarrels. The boiler was never used at a greater working pressure than 50lbs. to the square inch, and in the year 1902 the safety valves were adjusted to blow off at a pressure of about 35lbs. The boiler was insured with the British Engine Boiler and Electrical Insurance Company, and was periodically inspected by their inspectors from 1896 until 1906. In May, 1911, the insurance was discontinued, and no further inspections of the boiler were made. On April 22nd last, while the stoker was away for about 20 minutes during the dinner-hour, an explosion occurred, one of the flues rupturing longitudinally for about 4ft. 6in., and forming an opening about 8in. in width at the centre. The rush of steam wrecked part of the brick wall separating the boiler from the engine-house, but fortunately nobody was injured.

Mr. Warner, in giving the judgment of the Court, said Mr. Butcher did not appreciate the serious consequences to the boiler of the intermittent falling of rain through the defective roof of the boiler-house on to the back part of the boiler and on to the brickwork adjacent to the boiler. The Court, he said, could find no excuse for Mr. Butcher's negligence in not having given facilities for a thorough examination of the boiler, and would have dealt with Mr. Butcher severely but for the fact that he had failed in his business owing to events over which he had little control. In the circumstances, the order of the Court was that Mr. Butcher should pay towards the expenses of the enquiry the sum of £15.

World's Mining Statistics.—The Chief Inspector of Mines, in a general report to the Board of Trade, gives statistics relating to persons employed, output, &c., of the mines and quarries in the British colonies and foreign countries in 1910. This shows that the number of persons engaged in mining and quarrying at home and abroad in 1910 exceeded 6¼ millions. Of this total, roughly speaking, nearly one fifth were employed in the United Kingdom, and more than one third in the British Empire. More than half of the total number were employed in getting coal alone, Great Britain employing nearly 1,033,000, the United States over 725,000, Germany over 694,000, France nearly 197,000, Russia (1908) over 174,000, Belgium nearly 144,000, Austria over 131,000, and India nearly 116,000. As regards the world's output of the most important minerals in 1910, the total amount of coal produced was 1,164 million metric tons, the value of which is estimated at nearly 420 million pounds sterling. The quantity and value, compared with 1909, show an increase of nearly 50¾ million tons in the output, and of 20 million pounds sterling in the value. The amount produced and its value by the three principal countries were:

	Metric tons.	
United States	455,045,030	£129,272,000
Great Britain	268,677,000	£108,378,000
Germany	222,375,000	£85,261,000

In the case of iron the United States, with an output of nearly 27¾ million tons, is considerably ahead of any other country. The German Empire, with over eight million tons, Great Britain with over five million tons, France with over five million tons, and Spain with nearly 1¾ million tons, come next. Taking coal mines, for which the figures are fairly complete, the death rate of the United Kingdom was 1·70, while for Austria it was 1·17, Belgium ·95, France 1·08, Japan 2·23, Germany 1·95, and the United States 3·79. The death rate for foreign countries generally was 2·45.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 58, New Bailey Street, Manchester.

MECHANICAL, 1911.

Reversible regenerative gas furnaces. Reynolds. 16041.
Furnaces. Fletcher. 20087.
Centrifugal governors and speed indicators. S. Smith & Son, Ltd., and Dorer. 20232.
Governing mechanism for elastic-fluid turbines. Vereinigte Dampfturbinen Ges. 20549.
Evaporating and drying apparatus. Kayser. 22326.
Jet condenser and feed water heater and purifier. Watson. 22351.
Steam boilers and water heaters. Howes & Bannerman. 22425.
Variable-speed gearing. Ryland & Louis. 22450.
Drills and sockets therefor. Barnes. 22498
Treatment of peat. Rigby & Testrup. 22501.
Temperature-regulating apparatus. Macardle. 22595.
Valves for internal-combustion engines. Cochrane. 22636.
Pistons and piston valves. Allen. 22713.
Variable-speed gearing. Crofton & Hunt. 22714.
Self starters for explosion engines. Christensen & Boult. 22770.
Rotary explosion motors. Verdet. 22820.
Apparatus for indicating temperature of bearings. Boaler. 22839.
Motor road vehicles. New. 22881.
Centrifugal fans or pumps. Whitfield, and Whitfield Fan Company. 23014.
Variable-speed gear. Johnson & Kilgour. 23148
Variable-speed transmission gearing. Yoxall & Thorneycroft. 23292.
Steam regenerative furnaces. Higgins. 23347.
Pressure release valve for use in connection with locomotive and other steam engines. Robinson. 23353.
Carburetters for explosion motors. Soc. du Carburateur Zenith. 24392.
Compressors for air and gas. Hurst. 24943.
Motor road vehicles. Alldays & Onions Pneumatic Engineering Company, and Simms. 25189.
Work-holders for metal-cutting machines. Matthews & Holmes. 25395.
Apparatus for measuring gases or liquids. Wilson. 25448.
Fluid-pressure regulating or reducing valves. David Auld and Sons, Ltd., Auld, and Graham. 25612.
Internal-combustion engines. Mills. 25885.
Steam engines. Shaw. 26074.
Gas scrubber. Davidson & Liversedge. 26979.
Method of and machine for extruding metal tubes and rods. Lake. 27923.
Internal-combustion engines. Gordon. 28311.
Micrometer gauges. Turner. 28727.
Die-casting machine. Whiteman. 29113.

1912.

Automatic lubricator for the cylinders of steam engines. Bureau. 453.
Starters for internal combustion engines. FitzGerald. 185.
Pipe or tube-cutting appliances. Tomlinson. 1519.
Pumping of condensed steam water to elevated feed-heaters in steamships. Weir. 2005.
Steam-turbine pumps, blowers, and air-compressors. G. & J. Weir, Ltd., and Petermöller. 3602.
Heating apparatus using vaporised liquid fuel. Von der Heyden. 3920.
Carburetters for internal combustion engines. Ayres. 5038.
Means for indicating the tension on belts. Dobson. 5143.
Engine packings. Talent. 5356.
Internal combustion turbines. Inrig & Inrig. 7733.
Steam generator fitted with superheaters. Babcock & Wilcox, Ltd. 8316.
Firebridges of marine boiler furnaces. Blake & Caldwell. 8540.
Ball bearings. Rennerfelt. 9011.
Carburetters for internal combustion engines. Dayton. 9208.
Rotary engines. Silvestri, Barasch, Schwarz, & Findenigg. 10624.
Turbine vanes. Fraser & Chalmers, Ltd., and Pochobradsky. 11706.
Rotary internal combustion engines. Sanchez & Baradat. 12560.
Water tube steam generators. Stirling Boiler Company. 12786.
Railway rail joints. Gorman. 13085.
Railway rail joints. Tolgen. 13161.
Steam engines and particularly locomotives using superheated steam. Adam. 13771.
Furnaces. Blair. 15480.
Means for ships' propulsion. Roellig. 19693.

ELECTRICAL, 1911.

Electro-magnetic means for the transmission of power. Balsillie. 22690.
Electrical insulators. Ellis, and British Insulated & Helsby Cables, Ltd. 23663.
Means for increasing the power factor and overload capacity of alternating-current synchronous machines. Kapp. 24823.
Magnetic brakes of tramcars. Conaty & Ketley. 26969.

1912.

Electric switches. British Thomson-Houston Company. 459.
Suspenders for overhead electric cables. Elder. 4975.
Electric motor control systems. Allgemeine Elektricitäts Ges. 5803.
Single phase induction regulators. Siemens-Schuckertwerke Ges. 7697.
Electrically propelled motor-cars. Allmanna Svenska Elektriska Akt.-Bolaget. 7992.
Electric heating apparatus. Berry. 13861.
Electric switches. Merriam. 14751.
Telegraphic relays. Muirhead & Muirhead. 17955.

METAL QUOTATIONS.

TUESDAY, NOVEMBER 5TH.

Aluminium ingot	82/- per cwt.
,, wire, according to sizes, &c. ......from	102/- ,,
,, sheets ,, ,, ... ,,	120/- ,,
Antimony ......£39/-/- to	£40/-/- per ton.
Brass, rolled	9⅛d. per lb.
,, tubes (brazed)	11¾d.
,, ,, (solid drawn)	10d.
,, ,, wire	9⅛d.
Copper, Standard	£75/15/- per ton.
Iron, Cleveland	67/- ,,
,, Scotch	73/- ,,
Lead, English	£18/10/- ,,
,, Foreign (soft)	£18/7/6 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/12/6 per bottle
Silver	28 13/16d. per oz.
Spelter	£27/7/6 per ton.
Tin, block	£228/5/- ,,
Tin plates	15/6 ,,
Zinc sheets (Silesian)	£31/5/- ,,
,, (Stettin; Vieille Montagne)	£31/10/- ,,

Mining Machinery Exhibition.—A Mining Machinery Exhibition will be held at the Agricultural Hall, Islington, London, N., from May 29th to June 7th, 1913. Particulars may be obtained from the Exhibition Offices, 43, Essex Street, Strand, London, W.C.

The State and Industrial Disputes.—An interesting paper on "State Regulation of Industrial Disputes" was read by Mr. A. H. B. Constable, K.C., the president of the Scottish Society of Economists. He said the outstanding feature of recent industrial struggles had been the attempt of organised labour in vitally important industries to exert pressure on employers by stopping supplies to the consumer—in other words, to put in operation the principle of the general or sympathetic strike. When the stage of actual industrial war was reached the function of the Government was to preserve law and order by enforcing contracts and preventing and punishing destruction of property and violence to person. If they could not compel the individual striker to work they must, if the industry was one on which the continued maintenance of the life of the community depended, use all means at their disposal to ensure a supply of necessaries for the population. They must endeavour to mediate between the parties or pass special legislation for the redress of their grievances. The attempt made by the legislation of 1871-1906 to place trade unions in the position of being at once within and beyond the law was unsatisfactory and unjust. Any scheme of general compulsory arbitration and prohibition of strikes and lock-outs must at once be dismissed as impracticable. It would ultimately involve the fixing by legislative enactment of a minima of wages, hours of labour, and other conditions in all employments. They seemed to be drifting towards such a system, and it could not be suddenly applied without imminent risk to national bankruptcy. There were, however, certain cases in which the principle of compulsory arbitration and prohibition were worthy of consideration, such as disputes as to the meaning of existing industrial contracts, disputes in State owned and conducted industries and services, such as the Post Office, railways, &c.; and disputes in public utility services—the supply of water, light, public transport and communication—which were necessary to the community. They could not afford to wait indefinitely the results of experiments in other places for the solution of the problem of industrial unrest. Each country must endeavour to solve its own problem in its own way.



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Shortness of Water and Fusible Plugs.

LOCOMOTIVE boilers on railways are remarkably free from mishap as a rule, and if anything does give way the facts are usually fully revealed at the Board of Trade enquiry. In this latter respect, however, a failure on the South-eastern and Chatham Railway at Tunbridge Wells on April 29th last, and which has just been reported on, is an exception. A train of empty carriages had travelled about $1\frac{1}{2}$ miles from Tunbridge Wells Station when the roof of the firebox collapsed (as shown in the illustration on page 603), and the engineman and fireman were blown off the footplate and very seriously injured. Mr. Carlton, who subsequently investigated the matter for the Board of Trade, had no difficulty in arriving at the conclusion that the failure of the crown was due simply to overheating from shortness of water, and, indeed, the facts do not admit of any other conclusion. The crown-plate was not structurally weak, and yet it bulged locally and stripped away from the greater portion of the suspension stud stays holding it to the cross girders, whereas the other portions of the firebox were practically uninjured. Further, the whole area of the crown bore obvious traces of overheating. The puzzling thing about the case is how the overheating came about. There was an ample supply of water in the tender, while the fireman affirmed that the gauge glasses were three-fourths full just before the explosion, and when examined the water gauges and injector fittings were found to be clean and in good working order. The condition of the gauges themselves thus disposed of any suggestion that they might have given a false reading and so misled the men on the footplate. It would have been better if the driver could have corroborated the fireman's evidence, but unfortunately this was not possible, as, after recovery from his injuries, his mind was a complete blank from the day before the explosion to 10 days afterwards, when he regained consciousness in the infirmary. The facts as revealed by the firebox crown and the condition

of the fittings cannot be reconciled with the fireman's statement that the gauge glass was three-quarters full, which would give a water level of 5½in. above the top of the crown-plate just before it collapsed. The inevitable conclusion is that he was mistaken, and that, through some oversight or other, an empty gauge glass was mistaken for a full one. A feature of the explosion worth noting is that the crown plate was fitted with a fusible plug, which had melted out, but failed to give any warning because the orifice was almost closed with scoria and hard scale. As the plug had been renewed about 2½ months previously, it shows how these fittings may be rendered useless by comparatively brief neglect, and the necessity of keeping them under observation. There is a tendency for attendants to overlook this fact, and to imagine that because there are no movable parts such fittings will look after themselves. This is a mistake, not merely do the fire and water sides of a fusible plug require to be kept clean if it is to perform its duty properly in the event of overheating from any cause and allow steam and water to escape and put out the fire, but the fusible metal itself requires to be renewed at intervals, since the alloys used are liable to undergo deterioration when exposed for a long period to the working temperature of the firebox crown. For this reason they should not be kept in service for more than two years. No objection could be urged against the plug on this score in the case under notice. As a matter of fact, it performed its duty by melting and running out. The failure of the steam to escape was due to an accumulation of scale on the water side which was sufficient to resist the steam pressure when the plug was melted. The type of plug adopted is not stated in the report, but very often the fusible plugs of locomotives are of a primitive kind consisting practically of a small lead rivet, and this does not compare in efficiency with the carefully thought-out designs generally adopted in stationary boilers, where the alloy is arranged in a thin annulus which is easily fused when the danger point is reached, and liberates a central core that ensures efficient action. We have known of many cases of explosion where simple lead rivets have failed to act properly, because as soon as a slight perforation has taken place the escaping steam has prevented any further melting.

Boiler Corrosion.

FEW features about boiler working have had more attention paid to them at one time or another than internal corrosion or wasting of the plates through the action of the feed water. Boilers are, of course, liable to waste outside as well as inside, but the source of the latter can be detected by careful inspection, and if preventive measures are taken to stop the dampness from which it nearly always springs the wasting can be arrested. Internal corrosion, however, manifests itself in such a variety of freakish ways that it is difficult sometimes to deal with. Experiments and investigations have been made without end, but it cannot be said that these aid materially the methods of dealing with the trouble derived from practical experience, and a perusal of a survey of some recent experiments by Prof. Heyn and Bauer, of the Prussia National Physical Laboratory, given by Mr. Stromeyer in his annual memorandum to the Manchester Steam Users' Association, tends to confirm us in this conclusion. The experiments as laboratory tests were very laborious, and they cannot be said to lead to anything very practical, or teach more than is already known. The corrosion caused by boiler feed water is due almost entirely to the oxygen and carbonic acid of the air which it has absorbed when in contact with the atmosphere. Some of the old-fashioned remedies in boiler practice, which consist of the insertion of copious quantities of organic substances into the boiler at cleaning time, are not quite so superstitious as superficial thought might lead one to think, though the carcase of a pig and a half-load of potatoes does, to an outsider, seem rather like a propitiatory offering to some mysterious corrosion god. The function of such prescriptions, however, is simply that of deoxidisers to render the free oxygen in the water harmless, and these primitive organic materials are now more generally replaced by tannin compounds. It should be noted, however, that to be most effective they should be associated with an alkali and introduced continuously with the feed. Heyn and Bauer's experiments, it may be added, confirm two conclusions already well known, viz., that most ammonia salts are powerful corroders of iron, as is shown by the serious wasting when feed waters are contaminated with waste liquors from gasworks, and that severe pitting may be set up if sodium carbonate is added to waters impregnated with common salt. Mr. Stromeyer some years ago discussed in an interesting manner and at some length the various types of water-softening plants that were then in use, and we are pleased to learn it is his intention in the near future to deal with this subject afresh, and to report how the various methods of softening water have answered in practice.

COMMERCIAL DEVELOPMENT OF THE ELECTRICAL INDUSTRY.

IN the course of his inaugural address, delivered before the Manchester Section of the Institution of Electrical Engineers, Mr. Arthur A. Day, the chairman, said the application of electricity to every-day life was of national importance, inasmuch as it involved such large issues as the abolition of the smoke nuisance in our large towns, the conservation of our national supply of fuel, the utilisation of waste products, and many other problems of a like nature. The first essential to the increased use of electricity was a cheap and efficient supply; this they were now in a fair way to attain in large towns and cities, but notwithstanding this the increase in output was not advancing as it should. The main problem was commercial rather than technical. The increased use of electricity involved doing everything on a larger scale, from power station to publicity.

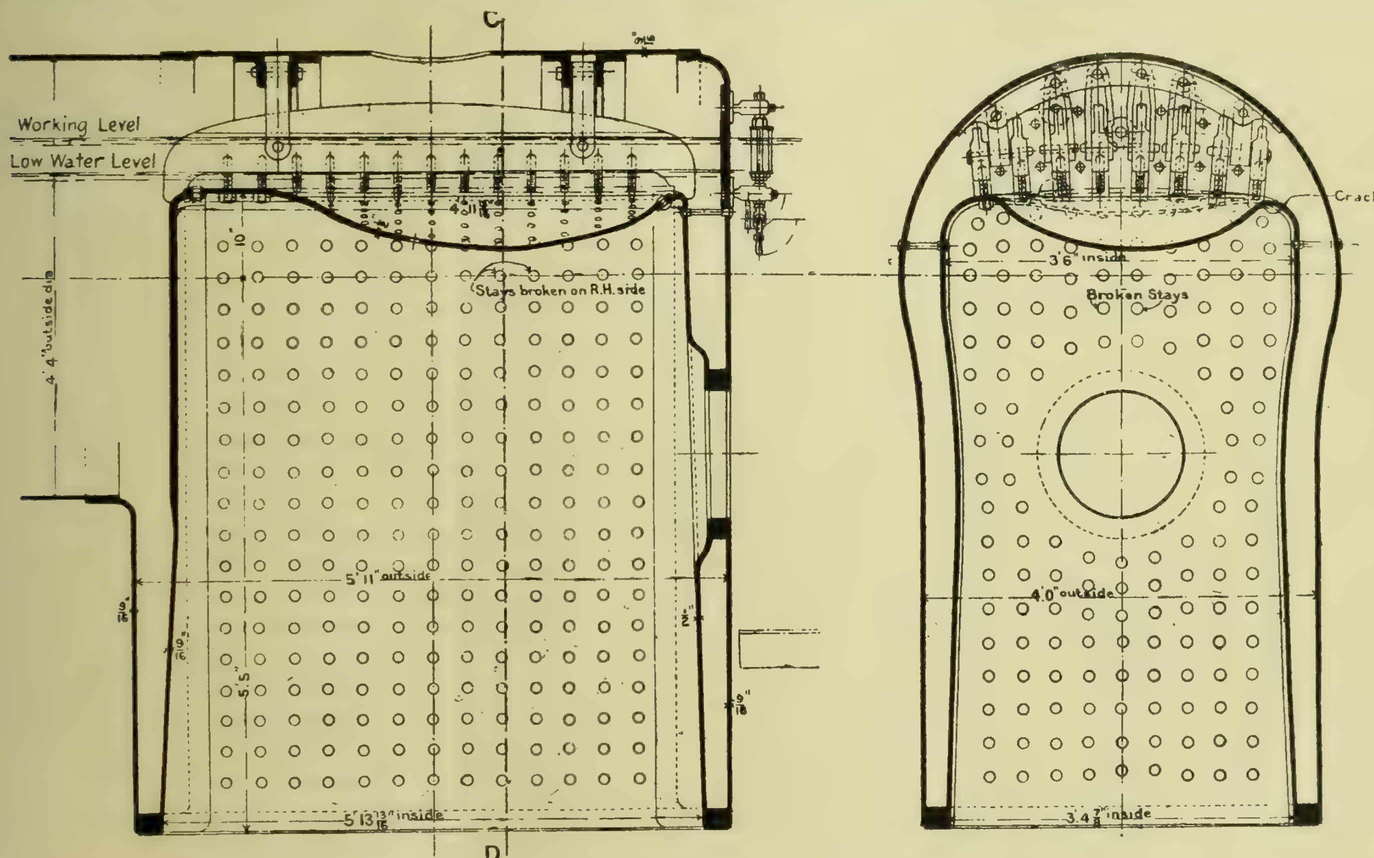
In England there were, he considered, far too many generating stations, and too great a variety in the types of current supplied, necessitating different classes of apparatus for its application. This prevented the manufacturer from producing in quantity, and so increased the cost of apparatus, and, moreover, it confused the ordinary man. Simplicity was undoubtedly a large commercial asset. With the example of the different gauges of railways and tramways before them, was it not of the utmost importance that some effort should be made to ensure uniformity, if not in detail, in main essentials? Even in smaller matters very large economies were to be obtained by uniformity. Mr. Watson, in his address to the Section in 1909, pointed out that a capital saving of £500,000 could be obtained by the interconnecting of the electric supply networks of the towns just round Manchester. Their supply stations and networks were going to be, in the future, infinitely larger than they were that day, and if extensions, when made, were controlled by certain general considerations, and plant, when replaced, was similarly dealt with, they would soon see a great difference, and a greater tendency to uniformity. It would not be necessary to aim at uniformity of the whole country on one system; the system most in use in any given area would, he supposed, be generally accepted as the system for that district.

If it were conceded that these things were desirable, viz.: (1) Large generating stations with large units, &c., in the interests of low cost of production; (2) co-operation between existing systems of supply, with a view to economising in the cost of station plant, and also in the cost of distribution; (3) uniformity of systems of supply as far as practicable, and at anyrate in adjoining districts, in the interest mainly of

the manufacturer, but incidentally also of the consumer, by reason of the reduced cost of apparatus—was it not within the scope of the Institution to do anything towards attaining these objects eventually, and moving in that direction now?

He suggested that committees should be formed of members of the Institution representing each interest involved, viz., supply authorities, manufacturers, contractors, and the commercial community. They would obtain all information necessary for a thorough consideration of the question in the area they were appointed to enquire into, and would recommend the lines on which existing supply authorities should extend, and so on to a main committee, consisting of delegates from the sectional committees, who would consider and revise the whole of the recommendations, if necessary. Having through these committees obtained the lines on which progress should be made, the Institution could approach the Government of the day, and seeing that co-operation with the Government. The danger was that, the cause of anxiety having for the time being more or less ceased, the matter would be shelved, and the obvious lessons to be derived from the strike lost sight of.

It should be a national matter to encourage any system of intensive culture of land, which would tend to lessen our dependence on foreign food. Electricity could be used in this direction. Was it too much to ask the Government for a grant, and to help generally to start this system on a large basis, seeing the national importance that the food supply might assume at any time? A comparatively small sum would effectually prove its profitable nature to the farmer, who would then adopt it from commercial motives, and if not, it would be the Government's business to see that it was done. Was it not possible for our Institution, in conjunction with the Government, to do something in this direction? He did not plead for Government ownership;



Collapse of Furnace Crown of a Locomotive Boiler through Shortness of Water (see page 601).

the movement would be in the interests of all concerned and also in the interests of national economy and system instead of chaos, he saw no reason why the said committee should not be allowed to co-operate with the Board of Trade and the Local Government Board, as these Government departments were important factors in the starting or extending of any supply undertaking, and would be able to influence considerably the type of supply started or extended. The whole process would be gradual, and would be intended to prevent the extension of the present want of uniformity and cohesion between systems rather than the enforcement of any particular system. It was essential that the Institution should be recognised more by the Government departments and taken more into their confidence. Without the assistance of the Government it would be practically impossible to carry out such a scheme as was suggested some little time ago by Mr. Ferranti.

Those who had had the responsibility of maintaining the continuity of electric supply during the past 12 months or so had had brought home to them more forcibly than ever before the importance of electric supply to the community; and how much more important would it become in the case of the larger schemes foreshadowed. It would, indeed, be a matter of national concern. The Government seemed to realise the seriousness of the position, judging by the anxious enquiries which they made during the strike as to how long the public supply was able to last. It seemed, therefore, a proper time to put forward a plea for a greater amount of he did not believe that that would be beneficial, but he thought they should have more recognition and help from the Government, seeing that the application of electricity was so vital to public interests.

Thorium.—In a lecture on "Thorium and its Compounds" delivered by Mr. E. White before the Institute of Chemistry, the lecturer said that thorium occurred in a large number of minerals in Norway, which were, however, found only in small quantities. Its chief commercial source at the present day was the monazite sand deposits in Brazil; similar sand occurred also in North America, India, Australia, Nigeria, the Straits Settlements, and South Africa. He referred to the importance of thorium in the gas lighting industry, the world's requirements in gas mantles being estimated at about 400 millions annually. He described the general methods employed in the extraction of the element, drawing attention to the difficulties which arose from the fact that in monazite it was associated with 10 to 12 times its weight of the cerite earths. The latter bodies so closely resembled thorium in the solubility and other properties of their salts that a sharp separation in one or two operations was not possible. Hence methods based upon fractional crystallisation and precipitation must be employed, thus rendering the extraction tedious and expensive. The finished product, thorium nitrate, was prepared in white crystalline masses or granules which were very soluble in water.

BOOK REVIEWS.

An Outline of the Metallurgy of Iron and Steel, by A. Humboldt Sexton, F.I.C., F.C.S., and J. S. G. Primrose. Manchester: The Scientific Publishing Company. 8¾in. by 6in.; 572 pp.; 273 illustrations; price 12s. 6d. net.

This book is designed to meet a need which all engineers must at times feel, viz., that of a single volume of moderate size and reasonable price which covers the whole field of the metallurgy of iron and steel. The want is not an easy one to meet, since the subject is so large. It furnishes, as we know, subject matter for two volumes of proceedings each year of the Iron and Steel Institute, and, with scientific progress, is of an ever-changing character. The authors are both well-known authorities, and Prof. Sexton's reputation as a writer on the subject needs no praise from us. Practical appreciation of it is afforded by the fact that this work has run to a second edition. In its preparation the authors have spared no pains to bring the subject right up to date. To do this has practically necessitated the re-writing of the work and materially enlarging the contents, especially in respect to the developments in electric steel melting and heat treatment, and the application of the microscope to the analysis and molecular structure of iron and steel. A feature of the book which deserves note is the copious way in which the text is illustrated with diagrams, photographic and sectional views to aid in describing working processes. We do not know of another work which comprises within a single volume so wide and thorough a survey of the subject, and we doubt not the appreciation accorded to the first edition will be equally extended to the one under notice.

* * *

Primer of Scientific Management, by Frank B. Gilbreth, Mem.Am.Soc.M.E. London: Constable & Co. 8½in. by 5½in.; 108 pp.; price 4s. net.

The general principles underlying what is termed scientific management have received most attention in America, probably because in that country labour is more costly than elsewhere and interference with its organisation by trade unions less pronounced. The author is well known for his motion studies of handicraft operations with a view to increasing the efficiency of workmen, and this little work is practically an essay on the principles of scientific shop management generally. Although the essay is interesting reading and would form good matter for a few articles in a technical journal, its interest to most readers would end with its perusal. The work is in no sense a reference book.

* * *

The Coking of Coal at Low Temperatures, with a Preliminary Study of the By-products (price 1s. London; Chapman and Hall), by S. W. Parr and H. L. Olin, has just been issued as Bulletin No. 60 of the Engineering Experiment Station of the University of Illinois.

This Bulletin gives the details of experiments in the carbonisation of coal at relatively low temperatures, not exceeding 750° Fah. The studies indicate that the bituminous matter in Illinois coal is in excess of the amount necessary to produce bonding material for the non-coking or cellulose residuum of the coal and that the best cokes are produced when mixtures of fresh coal and non-coking coal materials, such as coke breeze or powdered anthracite, are used. The tests show that the by-products consist of a gas of high illuminating power and heat value (1,030 B.T.U.), and tarry material which consist in the main of oils of low viscosity having marked oxygen-absorbing properties. In one important aspect, this work constitutes a study in smoke prevention from a chemical rather than a mechanical standpoint, and the results show that bituminous coal in a form for combustion without smoke is at least a theoretical possibility. An interesting feature of the work is the information it affords as to the theory of the coking of coal. The summary touching this point concludes that "for the formation of coke there must be present certain bodies which have a rather definite melting point," and further, that "the temperature at which decomposition and carbonisation take place must be above the melting point."

* * *

Calculations on the Entropy Temperature Chart, by W. J. Crawford, D.Sc. London: Charles Griffin & Co. 8in. by 5½in.; 74 pp.; price 2s. 6d. net.

The subject of entropy has been presented in so many forms and discussed from so many points of view that it offers few possibilities for fresh treatment, and although this little text book deals with the matter in a clear and intelligible manner, it can hardly claim in this respect to do more than what is already done by several others, in fact, the literature on this subject now appears to have reached that stage which has long been occupied by "Mechanics," about which almost every teacher feels it incumbent upon him to issue a text book to meet the needs of his own students. In saying this we do not imply anything derogatory, for, so far as it goes, no exception can be taken to the way in which the subject is presented, while an appendix of examination questions with helps to their solution adds to the usefulness of the book.

* * *

Industrial Chemistry: A Manual for the Student and Manufacturer. Edited by Allen Rogers and Alfred B. Aubent, in collaboration with numerous coadjutors. London: Constable & Co., Ltd. 7½in. by 5in.; 328 pp.; price 24s. net.

This is essentially a work of technical reference for the manufacturer and the workshop. There is scarcely any industry nowadays which is not brought at one or more points into close contact with chemical operations, or which does not occasionally call for special information of some kind with regard to raw materials or manufactured products, and from this standpoint the volume under notice will be found a convenient work of reference in most industries. Its contents include chemical data respecting engineering materials, though we should add, in regard to this section, it is extremely brief; water for industrial purposes; fuels, producer gas, sulphuric, nitric, and hydrochloric acids, commercial chemicals, limes, cements, oils, varnishes, fertilisers, gas, coal tar, and petroleum products, textiles, glues and gelatines, &c. As to the merits of the data presented, we cannot speak authoritatively except upon a small portion. The professional position, however, of the authors may, we think, be accepted as a reasonable guarantee of reliability.

BOOKS RECEIVED.

The Practical Mechanic's Handbook, containing useful rules and memoranda for practical men, by Franklin E. Smith. London: Constable & Co., Ltd.. 7½in. by 5in.; 328 pp.; price 4s. 6d. net.

The Properties and Design of Reinforced Concrete, instructions, authorised methods of calculation, experimental results, and reports, by the French Government Commissions on Reinforced Concrete, translated and abridged by Nathaniel Martin, B.Sc., A.M.Inst.C.E. London: Constable & Co. 9in. by 7in.; 119 pp.; price 8s. net.

Commercial Engineering, by Alfred Liversedge. Manchester: Emmot & Co., Ltd. 8¾in. by 6in.; 369 pp.; price 7s. 6d. net.

Measurement of Induction Shocks, by Ernest G. Martin, Ph.D. London: Chapman & Hall. 7½in. by 5¼in.; 117 pp.; 2s. 6d. net.

Electricity Made Plain, by George R. Peers, Assoc.M.I.E.E. Manchester: John Heywood, Ltd. 7in. by 4¾in.; 133 pp.; price 1s. net.

Proceedings of Sydney University Engineering Society, New South Wales, Vol. XVI. Published by the society at Sydney.

Magnetic Properties of Alloys: A general discussion held by the Faraday Society, April 23rd, 1912. Reprinted from the transactions; price 7s. 6d.

THE LOW COAL FEED GAS ENGINE.

Through the courtesy of Mr. A. M. Low, D.Sc., of 15, Great St. Helen's, London, E.C., we are able to present herewith particulars and illustrations of a novel design of internal-combustion engine operated by a direct feed of coal fuel. Mr. Low has, we understand, been experimenting with this type of engine for some seven years, and as a result, about two years ago he constructed a small engine of about 2 h.p. which ran successfully on solid coal direct. He has since been devoting his attention to the construction of a much larger engine, and the one illustrated, which is of the 4-cycle type of 80 h.p. to 100 h.p., is now operating successfully in a works near London. This engine, which has a 16in. cylinder by 25in. stroke and runs at 140 revs. per minute, is in reality a combination of a gas engine and gas producer. The coal, about the size of "beans," is fed into a hopper at the side of the cylinder. The diagram, Fig. 2, shows the method of operation. The coal is placed in the hopper and is drawn along each tube by the worms C operated by a ratchet from the half-time shaft. D is a division of the coal box, and the tubes have small holes cut in them where passing this division, which is connected direct to the inlet valve. The fuel is first heated on its passage through the exhaust box E and then raised to a still higher temperature on passing through the tubes within the combustion chamber. Air and steam are admitted to the ash box G, so that upon each suction stroke of the engine, air and steam are drawn over the hot carbon, producing air gas and water gas respectively, steam or water being only admitted when running at full load. When using bituminous coal, the coal gas that is given off at the initial stages of heating is drawn also with the other gases into the cylinder, extra air being admitted as required. Heavy overloads can instantly be met by cutting off air and steam from the ash box end, increasing the speed of the worms, and running on a mixture of coal gas and the extra air.

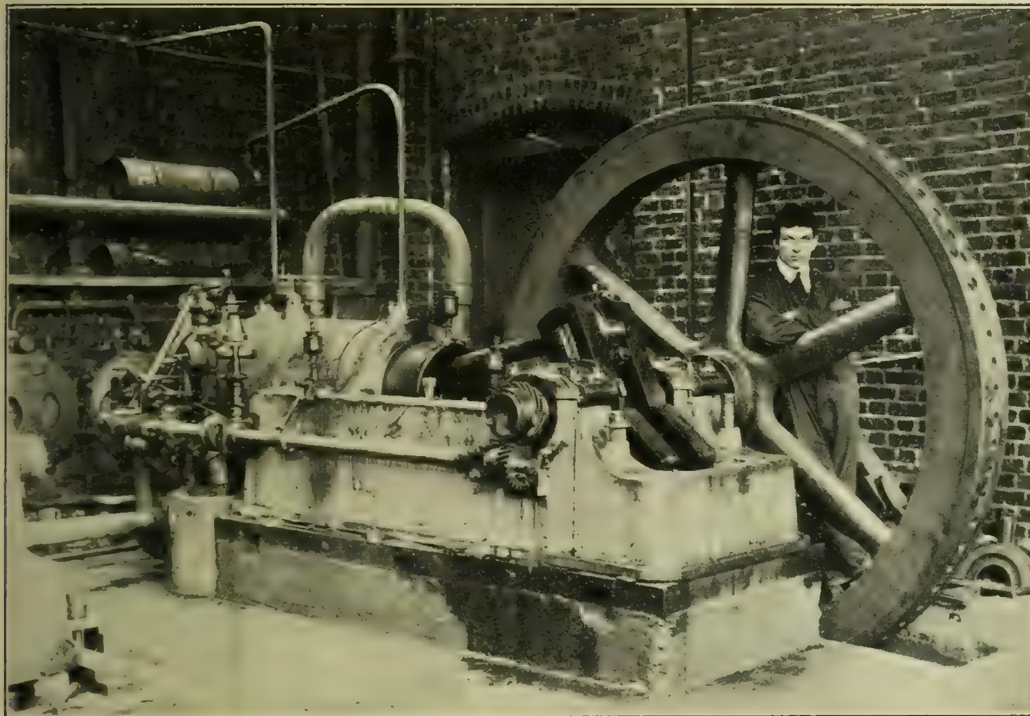


Fig. 1.—The Low Coal Feed Gas Engine.

One of the principal difficulties in connection with the successful operation of gas engines using producer gas obtained from bituminous coal is the tar trouble. This, Mr. Low claims, is obviated in his arrangement, and observes that if a tarry coal is heated slowly in bulk it coagulates and the tar, which may be imagined to include all other volatilised products, will be slowly driven off as a gas. This gas can of course be condensed by either cooling or compression, which is exactly what happens if a plain producer plant is used on "soft" coal. On the other hand, there is a well-known simple experiment that if coal is heated rapidly in small quantities and in a stream of steam or air the coal granulates and is flashed, the tar coming off as an atomised and not gasified spray, which can only be condensed by cooling under a compression of about 150lbs. to 200lbs. per square inch. For this reason the Low engine is not run at excessive compression pressures, and the cylinder pressure, except when firing, *i.e.*, heating, is taking place, never rises sufficiently to condense any of the tar by-products, which are passed straight out through the exhaust, the latter on analysis showing the presence of nearly the whole of the tar. Some of it is naturally "cracked" in the cylinder. The engine is, it is claimed, thus enabled to run direct on the coal, which is flashed exactly as water is treated in a flash boiler.

The engine runs, according to figures furnished by Mr. Low, on about ½lb. of coal per brake horse-power per hour. Inferior qualities of fuel may be used, from slack at 5s. per ton upwards. The efficiency of the plant is due to the fact that the waste heat of the engine is utilised in the production of the gas. The engine can be operated at a high temperature without fear of pre-ignition, while the space occupied is practically no greater than that of a similar powered engine without its producer plant. As regards safety, there is never any large body of coal in a state of incandescence nor of free gases, as the engine only produces gas for its immediate needs. At starting the engine is simply run on coal gas or oil, the change over to solid fuel being made by means of a two-way cock. This operation takes about 10 minutes. A pipe leads from the ash box to a water sump, which acts as a safety trap in the event of the small body of gas in the tubes becoming prematurely ignited.

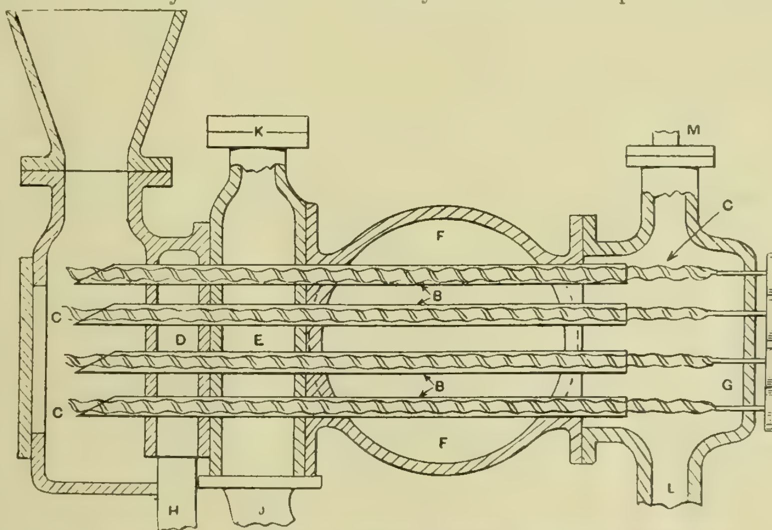


Fig. 2.—The Low Coal Feed Gas Engine. Section through Gas Producer.

THE TURBO-CONVERTER; A HIGH-SPEED DIRECT-CURRENT GENERATING UNIT.*

BY F. CREEDY, A.M.I.E.E.

The present paper describes an attempt to supersede such a mechanical monstrosity as the high-speed commutator of the ordinary direct-current turbo-generator by a construction

* Abstract of paper read before the Manchester section of the Institution of Electrical Engineers, November 5th, 1912.

which, though differing from current practice, is far less fundamentally objectionable. The fundamental difficulty, of course, in the design of a direct-current turbo-generator is the collection of the current from the rapidly revolving commutator, and for this, in spite of the engineering skill

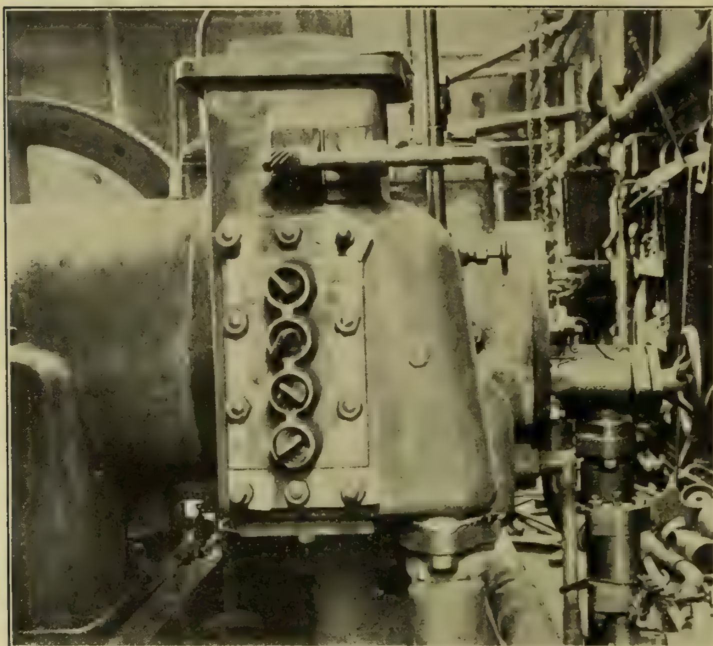


FIG. 3.—THE LOW COAL FEED GAS ENGINE. VIEW OF THE COMBUSTION HEAD FROM THE HOPPER SIDE.

lavished on the subject, there would appear to be no remedy, except reducing the rate of revolution of the commutator. In order to do this, Mr. H. M. Hobart has proposed the use of an alternating-current generator driving a rotary converter of the ordinary type, but this proposal has not often been adopted in this country, presumably through fear of the cost. Another plan which has had a certain measure of success is the use of double helical machine-cut gears which are now obtainable in sizes suitable for transmitting large powers.

The present paper describes a new method devised by the writer which may be regarded, to some extent, as a combination of the two mentioned above, in that an alternating-current generator of the induction type feeding a rotary converter is employed, the induction generator being used at the same time as a species of electromagnetic gear. By this means it is possible to reduce materially the size of both the rotary converter and the alternating-current generator, since, while in Hobart's proposal it is necessary to have both capable of delivering the full output of the system, in the writer's plan the output of the system is the sum of the outputs of the component parts, each of which therefore need only have half the capacity of the set.

The turbo-converter, then, in the form in which it has so far been developed by the writer, consists of an induction generator combined into one machine with a rotary converter, one member (preferably the primary) being mounted on the converter shaft and revolving with it, and the other, usually the squirrel-cage rotor, being mounted on the turbine shaft. Fig. 1 shows a diagram of connections of the device. By mounting the generator primary on the converter shaft, instead of having it stationary as in Hobart's proposal, we make use of the driving torque required by the induction generator, or, in other words, the resistance which its rotor opposes to being revolved by the turbine, in order to drive the converter, which is thereby caused to generate direct current in addition to its function as a converter.

Let us take, by way of example, a 4-pole generator and 4-pole converter. Let the converter be running at 1,500 revs. per minute, say, and let the 3-phase induction generator be connected to 3-phase tappings on the converter armature through the hollow shaft. At 1,500 revs. per minute 3-phase currents at 50 cycles will flow through the tappings on the converter armature. These tappings are so connected that the revolving field of the induction generator rotates the same way as the converter armature. In a 4-pole machine with 50-cycle excitation the revolving field will also go at 1,500 revs. per minute relative to the primary winding which produces it. Hence the total speed of the revolving field will be 3,000 revs. per minute, the sum of its speed relative to its primary and that of the primary itself. The squirrel-cage rotor, and therefore, of course, the turbine will go at approximately the same speed as the field. Hence we have obtained an apparatus in which the generator only runs at a fraction of the speed of the turbine.

In addition to its function as a direct-current generator, the converter, of course, changes the power of the induction generator, equal in amount to its own, into a direct-current form, and the total power flows out of the commutator of the set. The reader will not fail to remark the analogy between the present apparatus and the well-known and very successful motor converter of Bragstad and La Cour. There are, of course, fundamental differences between the principles of action of the two machines, but the analogy is sufficient to lead us to hope that the newer machine may find a sphere of usefulness similar to that of the older.

The reasons for the use of an induction rather than a synchronous generator would appear at first sight to be equally applicable. These reasons are few but conclusive: (1) If a synchronous generator were employed it would be necessary to synchronise the two revolving elements every time the set was started. (2) Owing to the presence of two sources of magnetisation in the set—one in the converter and one in the generator field—it would be possible for the set to "hunt" if overloaded, and for it to fall out of step if accidentally short-circuited, and be incapable of picking up

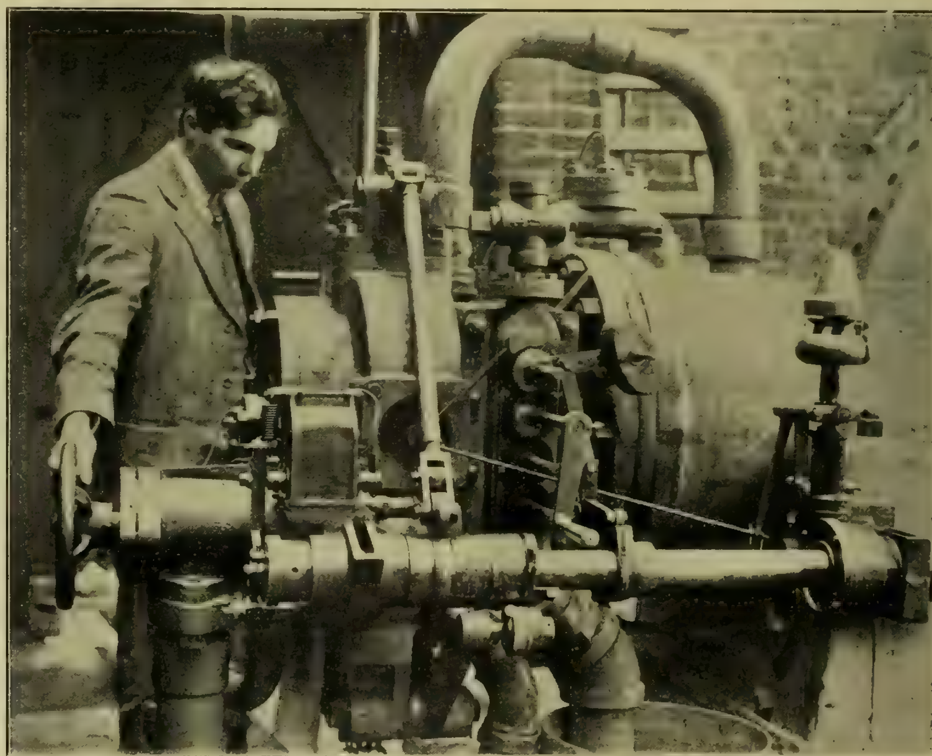


FIG. 4.—THE LOW COAL FEED GAS ENGINE. VIEW OF COMBUSTION HEAD FROM THE ASH SHOOT SIDE.

again. (3) Collector rings would be required on the high-speed element to excite the field.

The converter portion of such a set will be distinguished from an ordinary rotary converter by a number of peculiarities of design.

1. Owing to its function as direct-current generator, it will require more copper on the armature than a standard converter—exactly the same amount, in fact, as the converter portion of a motor converter.

2. As the field of the converter has to perform the double function of magnetising both converter and induction generator, it will necessarily be somewhat heavier than that of an ordinary converter.

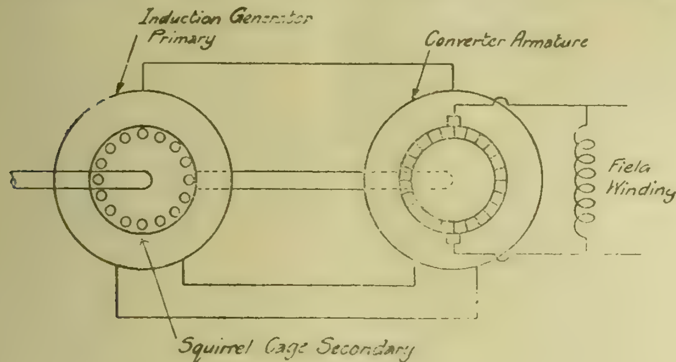


FIG. 1.

The magnetising current of the induction generator, in fact, differs 90° in phase from the working current, and circulates in the converter armature in such a position as to directly demagnetise the field of the converter. This field, therefore, must be supplied with an extra number of ampere-turns sufficient to counterbalance the magnetising current of the induction generator.

3. The drop in speed of a turbo-converter set from no load to full load would at first sight appear to be considerable, as the "slip" of the induction generator is added to the drop in speed of the turbine.

However, if the ratio of speeds of the turbine and converter are, say, 2 : 1, the effect of the slip on the speed of the converter is reduced in the same ratio, so that the resultant drop in speed is much less than might have been anticipated.

If we neglect the slip, the general rule for finding the "gear ratio" of a set having any number of poles is as follows: "Divide the number of poles on the induction generator by the sum of those on the converter and the induction generator, and the result will be the ratio of the converter speed to that of the turbine on no load."

There should be no difficulty in a machine of any size in reducing the slip of the squirrel-cage induction generator to 2 per cent., so that its effect on the converter speed will be very slight. The slip in the induction generator might appear to have a seriously injurious effect on the regulation of the set. Investigation, however, shows that while the series field of such a set requires to be a little stronger than on an ordinary generator in order to offset this, yet the effect of the slip is of quite small magnitude.

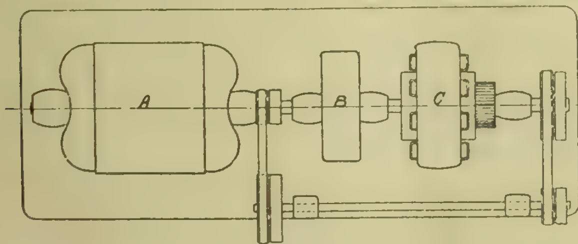


FIG. 2.—STARTING ARRANGEMENT FOR TURBO-CONVERTER.

4. Such a set can very readily be employed as a 3-wire set. All that is necessary is that the induction generator be connected in "star" and a tapping led from the neutral point to a collector ring, the brushes on which are connected to the neutral wire of the system.

5. The turbo-converter cannot be started from the steam-turbine end without auxiliary means. The steam turbine and squirrel-cage rotor attached will start up alone, while the converter portion remains stationary without showing any tendency to start. It is necessary to bring the converter up to a sufficient speed to generate enough voltage to excite the induction generator before the primary and secondary of the latter can get into step.

Methods of starting may be divided into two classes—electrical and mechanical. Let us take electrical methods first. (1) If a supply of direct current is available, the converter may be started up as a direct-current motor, when it will bring the turbine up with it to its rated speed of twice or more that of the converter. Steam can then be admitted, and the set will be ready for load. This is by far the best plan where applicable, but of course it requires an appreciable supply of electric power to enable it to be used. (2) Another plan requiring only a very small supply of power is the following: Means are provided for causing a direct current to circulate in one of the phases of the induction generator during the starting period. The generator so excited acts as an electric clutch, which will bring both elements up at the same speed, and may be automatically thrown out of action when the converter reaches the desired speed.

Coming now to the mechanical methods: (1) One of the best mechanical methods is that illustrated in Fig. 2. By means of an auxiliary idler shaft the turbine is belted on to the converter by the use of pulleys, which may conveniently be arranged to give the same velocity ratio as the induction generator. On starting the turbine, the converter is brought up to its correct speed by the agency of the belts, and as soon as the field switch is closed will be ready for load. The belts may then be run on to loose pulleys and the idler shaft stopped. This may be done by hand or automatically by means of a solenoid operated by the voltage across the converter brushes. Gearing could be used instead of belts in the above method, but would probably be less satisfactory. (2) An auxiliary turbine might be used to start the converter. (3) Primary and secondary of the induction generator might be coupled by a centrifugal clutch releasing when the converter reached its rated speed. (4) They may be coupled by a clutch operating when the torque between primary and secondary exceeds a certain value. A rudimentary instance of such an appliance is the device occasionally useful for experimental purposes, wherein primary and secondary are tied together by means of a predetermined number of thicknesses of thread.

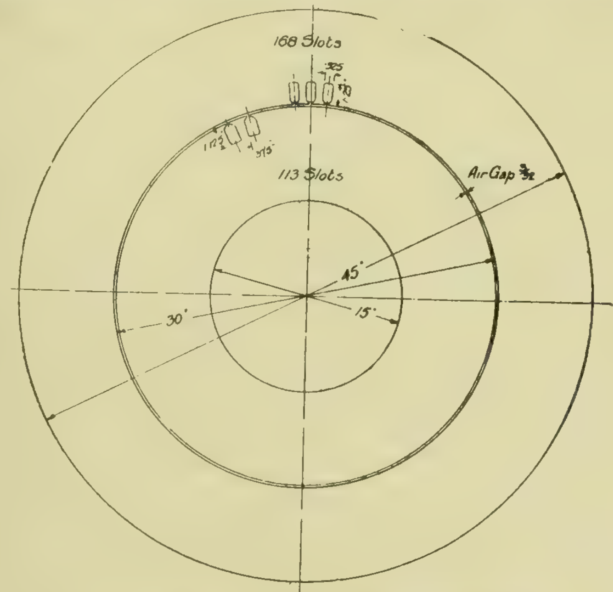


FIG. 3.—PUNCHING FOR 500 KW. INDUCTION GENERATOR.

When the machine reaches an appropriate speed, the torque between the two becomes sufficient to burst the thread and the two portions of the generator fall into step. When we come to criticise these methods with a view to picking out one for practical application, we find that all of them except the first electrical and the first mechanical methods are subject to the following criticism. So long as everything is in perfect order all of them will operate all right, but if the clutches or switches required failed to operate as

expected, the converter would run the risk of being raised much above its rated speed, the result of which would very likely be disastrous. Means could probably be found to prevent this, but on the whole it seems better to adopt a method where this criticism cannot arise.

The first electrical method described is not applicable in the absence of a considerable supply of electrical power,

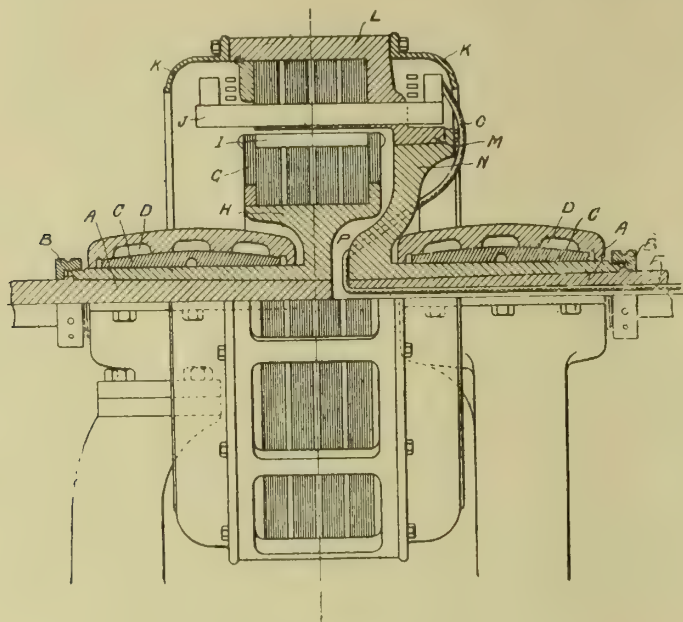


FIG. 4.

hence we come to the conclusion that the best method of starting is by means of belts and an idler shaft as described.

Two different forms of mechanical construction are possible for the turbo-converter. Firstly, the "flywheel" type, or secondly, that sketched in Fig. 6, which may be called the "spinner" type. In this type the squirrel-cage rotor forms the inner element, and is driven direct by the turbine. Surrounding this is a second element, the "spinner" capable of free rotation and also supported by means of ball bearings or the like on the same bearing pedestals in which the squirrel-cage rotor runs. This element bears the primary winding of the induction generator on its inside surface and the armature winding of the converter on its outside surface, being fitted with a commutator and brushes in the usual way. Outside of this again is the field ring of the converter, carrying the pole-pieces and their windings, &c.

The author, however, has hitherto devoted his attention chiefly to the other or "flywheel" type of design, perhaps chiefly because it permits of the use of a standard design of converter. The cardinal feature of this, of course, is that both primary and secondary are "overhung," or, in other words, supported by a single bearing. The most essential feature of any single-bearing construction is to reduce the overhang of the centre of gravity of the overhung mass beyond the bearing-nose as much as possible. It will be found in every case that the design adopted enables us to reduce this overhang to a matter of a few inches beyond the bearing-nose even in the most extreme cases, and for sizes of 500 kw. In order to do this, an induction generator design of large diameter and short length must be adopted.

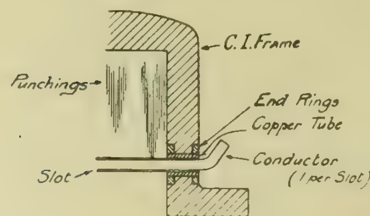


FIG. 5

We need have no anxiety as regards the effects of centrifugal force on the primary. It is merely necessary to take care that the primary end connections are well anchored in any convenient way. The peripheral speeds of the secondary are also quite moderate. A squirrel-cage rotor is, of course, ideal for high-speed designs. As there is only one bar per slot which can be pushed through from the end there is no difficulty in thickening the overhanging lip of the slot sufficiently to take care of the centrifugal force of the bar.

The only point which need cause us any anxiety is the short-circuiting ring of the squirrel cage. This cannot be made of steel, as it must consist of a high-conductivity non-magnetic material. In this connection I wish to draw attention to the properties of aluminium for high-speed work. It will be found, on calculation, that for all high-speed work aluminium gives a factor of safety only inferior to that of good steel on account of its extreme lightness. Probably some of the new light alloys are still better in this respect. At present prices, moreover, aluminium is, volume for volume, cheaper than any other material except cast iron and an ordinary grade of steel, again on account of its lightness. As regards conductivity, it is a commonplace that an aluminium high-tension line is cheaper than a copper one of the same conductivity, so we may feel reassured on this head. Hence, if we adopt the end-ring construction shown in Fig. 4, in which the end ring is made of rolled aluminium sheet, we have an ample factor of safety against centrifugal force.

Fig. 4 is a sketch, approximately to scale, showing the mechanical design of the induction generator. It will be seen that the centre line of the secondary only overhangs the bearing-nose by little more than an inch, while the slowly-revolving primary is overhung by approximately 9in. We may estimate the weight of this, including everything, as not over 3,500lbs., so that with an overhang of 9in. only

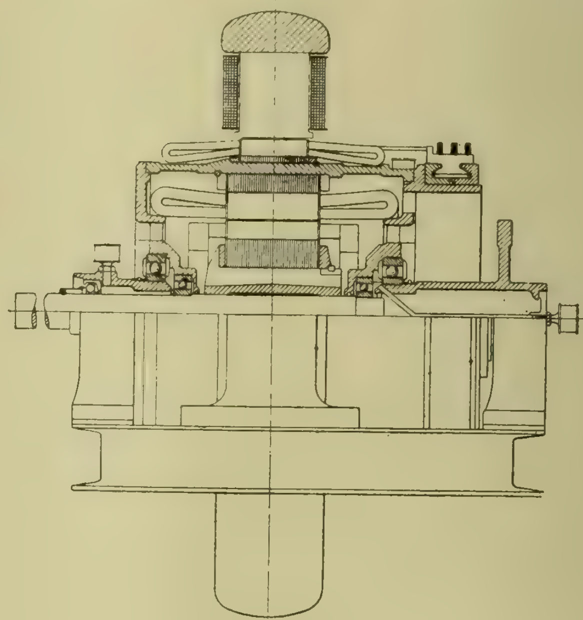


FIG. 6.

and a speed of 600 revs. per minute we are well within the range of flywheel practice.

The cardinal features of the design used to obtain these results are two in number:—

1. The primary frame is made of a non-magnetic material in which a number of holes are cast corresponding to the stator slots. Through these holes the stator bars are brought and so the stator winding is kept outside the frame. An alternative construction not requiring the use of a non-magnetic frame is shown in Fig. 5.

By this means we obtain the following advantages: (*a*) The overhang of the primary is reduced very much, as we do not have to allow space for the end connections inside the frame. (*b*) The frame abuts solidly on the punchings all round, and there is no hollow space to cause mechanical weakness. (*c*) There is ample room for the end connections, and they do not have to be cramped in any way. Any engineer who, like the writer, has had to design end connections for a cramped space, will know how great an advantage this is. (*d*) There is ample ventilation for the end connections.

2. The other important feature of the design is the arrangement by which the joint between the two hubs on which the primary and secondary of the induction generator are built up is made inside the bearing instead of on the projecting part of the shafts in the usual way. This enables us to have a quite ample and rigid bearing surface and yet only have a shaft extension of about 3in. in the set con-

sidered. The distance between the ends of the two bearing brasses is only about 11in., scarcely more than it would be with an ordinary flange coupling.

The machine in general consists of two forced lubrication, water-cooled bearings of large size supporting respectively one end of the turbine and the secondary of the induction generator, and one end of the converter and the primary of the induction generator. Mounted on the turbine shaft by a very long taper fit and keyway is a steel hub on which the secondary of the induction generator is built up. This is built up of punchings in the usual way, the end rings of the squirrel-cage winding being of aluminium in which holes are punched for the bars, these being afterwards riveted over on the outside. The primary is built up within a frame provided with holes on one side through which the insulated stator bars pass. This frame is mounted by a taper fit of ample area and keyway on another steel hub similar in general design to that used for the secondary, which is again mounted by a taper fit within the bearing on the converter shaft. In order to save the space taken up by a nut on the front end, these taper fits are arranged to tighten up from the back as shown. The leads are brought from the primary winding through the hollow shaft to the converter,

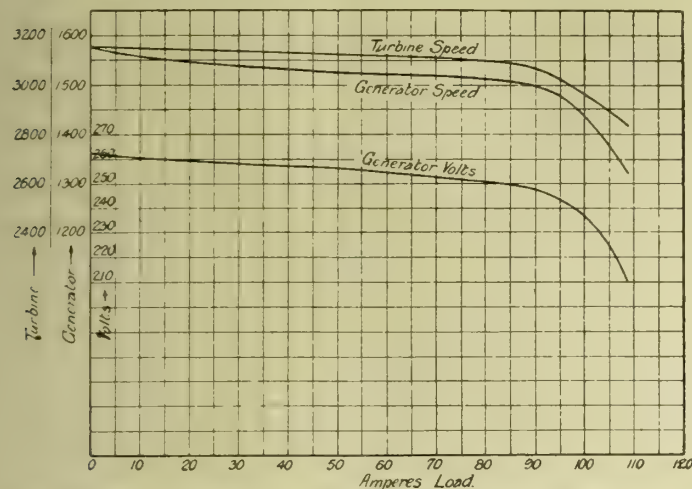


Fig. 7.—Load and Speed Curves as Shunt Generator (no Compounding).

Fig. 7 shows load and speed curves for the machine as shunt generator. In these curves the turbine speed is shown to one-half the scale of the generator speed. Since half the speed of the turbine is the synchronous speed of the generator, the difference between the turbine and generator speeds read off on the generator speed scale is the slip in revolutions per minute of the induction generator. It will be seen that the load was limited by the capacity of the turbine, as this began to fall rapidly in speed above 90 amperes load.

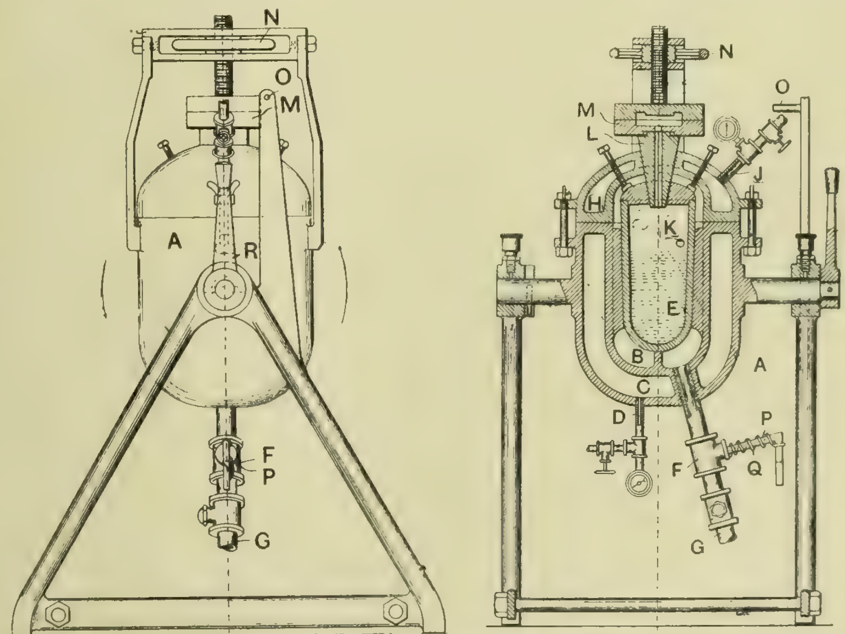
With the set arranged as a 3-wire machine in the manner described above, load was applied to one side of the system only, the other side being left entirely unloaded. The maximum difference in voltage between the two sides corresponding to full-load current on one side and no load on the other was $3\frac{1}{2}$ per cent. The total voltage fell somewhat as one side was loaded, but this, of course, could be corrected by ordinary compounding coils.

DIE-CASTING MACHINE.

The die-casting machine illustrated herewith has recently been patented by the Indiana Die Casting Development Company, 301-338, South McGill Street, Indianapolis, U.S.A., and has been designed with the object of providing a machine that may be quickly and easily operated by unskilled men, and adapted to make successively castings from different metals which require different treatment in melting them. The feature of the arrangement lies in the quick introduction and the rapid expansion or explosion of an explosive mixture for forcing the molten metal from a tilting containing crucible into the die after the metal has commenced to flow into the die, whereby no part of the metal will be deteriorated by oxidation. Means are also provided for mounting the crucible and insulating the same to prevent the radiation of heat, with a resulting cooling of the metal in the crucible. The construction makes use of a body oscillatably mounted in a supporting frame with means for clamping the die against the top of the frame and in communication with the crucible held with the frame.

The oscillating crucible containing or holding pot A has an inner wall forming a chamber B and an insulating chamber C, from which the air is exhausted through the pipe D extending through the outer wall. The inner chamber wall has four ribs, extending inwardly therefrom, and tapering slightly from bottom to top, and are provided for the purpose of holding a crucible E. A nipple screwed into the walls of the crucible-holder has a two-way valve F mounted on the end, and a pipe G is connected thereto for supplying a gaseous or other explosive mixture under pressure and introducing it into the chamber B when the valve F is opened. The pipe G is provided with a check valve. A cover fits upon the flat upper ring of the crucible container A so as to make an air-tight joint therewith, and is secured thereto by bolts extending through lugs cast integral with the cover and container, respectively, and has an inner or insulating chamber H from which the air is exhausted through the pipe J. Set-screws are used for holding the cover on the crucible.

The crucible E is provided with a small gas opening K through the wall above the level which the metal in the crucible will assume when melted and the crucible is upright. The crucible fits down within the chamber B and rests against and is secured by the inwardly extending ribs, before mentioned, and has a cap adapted to fit over its upper end which is held down by set-screws. The conical pouring



Figs. 1 and 2.—Die-casting Machine.

spout L projects through the opening in the crucible cover. The outer end of this spout fits into a shouldered portion in the die M, this die being held thereon by means of a screw having a handwheel N keyed thereon and with the upper portion of the screw threaded through a frame mounted on arms extending upwardly from the pot A. An upward extension from one of the frames carries a projection O thereon which will engage an L-shaped handle P of the two-way valve F when the pot A has been revolved about 170°, and cause the opening of this valve. The air exhaust connections D and J are provided with pressure gauges and valves. The valve F has an L-shaped handle P with a coiled spring Q about one leg with one end inserted in a hole in the valve body, and with the other bearing against the other leg and tending to keep the valve in a closed position.

The free end of the handle is cut obliquely, and has the outer part S connected to the main handle P by the spring hinge T (see Fig. 3). The oscillating movement of the pot is limited to an arc of 180° by means of a stop.

In operation a portion of the air in the insulating chambers C and H is exhausted in any desired way. The crucible E, containing molten metal which has been melted elsewhere in any desired way, is placed in the container and the cover placed on the crucible, after which the cover is secured upon the container A. The pouring spout L is then driven into place, the die M adjusted on the outer end of the spout and tightly secured thereon by turning the handwheel N and causing the screw to wedge against the upper part of the die. The pot A is then tilted toward the position shown in Fig. 3, by turning the lever R. After the pot has passed a horizontal position, the molten metal in the crucible E will flow through the spout L into the die M, and when the pot approaches a vertical position, having turned through an arc, say, of 170°, the extension S of the handle P will be depressed by the projecting lug O and cause

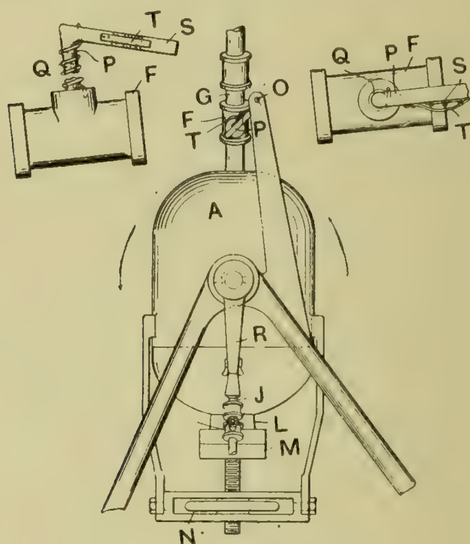


FIG. 3.—DIE-CASTING MACHINE.

the opening of the valve F. The gas valve lever remains in engagement with the projection O, while the pot turns through an arc of approximately 5°, and on passing out of engagement with the lug the valve is quickly closed under the action of the spring Q on the stem. This closing is accomplished before the pot reaches the vertical inverted position. Thus a gaseous mixture under pressure will be suddenly introduced into the chamber B and, passing through the hole K in the crucible E, will meet with the molten metal contained therein, ignite, and by the sudden increase of pressure resulting therefrom within the crucible the metal will be forced into the die. This sudden introduction of the charge and the explosion thereof at a desired time to drive out the metal closely resembles the introduction and ignition of the explosive charge in the cylinder of an internal-combustion engine where the piston is driven outwardly by the explosion. After the metal has been poured the pot is turned back to its normal position, and in such passage the lever extension S will again meet with the lug O, but the hinge T will allow it to pass by the lug O without actuating the valve, and the spring in the hinge will cause the extension S to return to its normal position. After the machine has been moved to its normal position, the die may be removed from the machine by turning the handwheel N, thus releasing the die. It will be readily understood that by this means of forcing the metal into the die none of the metal will be oxidised.

The main feature of the machine is the discharge of the metal into the die by reason of the explosion or quick expansion of an explosive mixture in the crucible, and also the employment of the heat-insulating chamber within the pot or surrounding the crucible so that the crucible may be transferred to the pot after it has been heated and the metal therein melted in a separate furnace, and yet the crucible be prevented from chilling for a reasonable length of time, during which, by successive die casting operations, a number of castings may be made from the same charge of metal in the crucible and until all of the metal therein has been used, without removing the crucible for reheating the metal therein.

THE OIL MOTOR SHIP "MONTE PENEDO."

ANOTHER oil engine driven vessel is, according to "Engineering News," shortly to be put into service in the South American trade, probably to ply between New York and Rio Janeiro. The ship is 360ft. in length and the breadth 50ft. It was built at the Howaldt Works of Kiel, Germany, and is designed for a speed of 10½ knots. The two 4-cylinder engines operate on the 2-stroke cycle; thus an impulse is obtained from each cylinder at each revolution. The engines were built by Sulzer Bros., of Winterthur, Switzerland, and represent the latest type of Diesel oil engines built by this firm. While most 2-stroke cycle Diesel engines previously built have had the scavenging valves in the cylinder head, on the "Monte Penedo's" engines the scavenging air is admitted through two rows of ports in the barrel of the cylinder nearly opposite the exhaust ports. The cylinder head construction is thus greatly simplified and the amount of gear required to be removed in order to take off the cylinder head to get at the piston is much reduced. Compressed air for scavenging the engine cylinders is furnished by a double-acting air compressor driven by a separate crank on the main shaft of the engine. The same crank also drives a 3-stage air compressor which furnishes compressed air at 900lbs. per square inch for spraying the fuel into the cylinders. There are two 50 h.p. auxiliary Diesel engines, one driving a generator for lighting the ship, the other driving an air compressor furnishing a supply of compressed air in case the air compressor on the main engine breaks down, and also furnishing an additional supply to serve for manœuvring the main engines when frequent starting and stopping is required as in entering or leaving a dock.

An interesting table furnished by the builders of the vessel shows the comparison of the engine equipment of this vessel and of an ordinary steam vessel of the same tonnage. The estimated saving in weight of the machinery of the motor vessel over the steam vessel is about 170 long tons. A motor vessel for a voyage to Buenos Ayres and back would require 432 tons of oil; a steam vessel with the latest quadruple-expansion steam engines would require 1,505 tons of coal, or with a triple-expansion engine 1,755 tons of coal. The total saving in weight in both machinery and fuel of the motor-driven vessel over the steam-driven vessel will average 975 to 1,200 tons. Converting this into cargo space, a motor ship will have available for cargo about 28,000 cub. ft. to 33,000 cub. ft. more than a steamship. A steamer will require 16 firemen and coal passers; the motor ship requires 6 labourers for the engines and donkey boiler service, or a reduction of 10 in the machinery force required.

British Foundrymen's Association, Scottish Branch.—At a meeting of the Scottish Branch of the British Foundrymen's Association held on Saturday last in the Royal Technical College, Glasgow, a paper was read by Mr. H. S. Primrose, Cathcart, upon "Metallurgical Control in the Brass Foundry." After describing the difficulties under which the brass founder has to work owing to the fumes arising from the molten metal, the lecturer detailed the usual methods of melting in crucible and air furnaces. Recent improvements consisted in utilising tilting furnaces either heated by an oil flame or in some cases by electric current. The control of the metal was advocated to be complete starting with the raw material and tracing it through all the departments until it was sent out as the finished product. The tests applied to it were not only chemical and physical, but where possible microscopical as well, as this was the surest way of detecting the cause of any irregularities in the metal. The methods of removing faults or preventing failures was also described and the beneficial effect of phosphor alloys in eliminating impurities during the melting specially commented upon. A short discussion followed.

INTERNATIONAL ENGINEERING AND MACHINERY EXHIBITION, OLYMPIA.—VI.

Messrs. Edward G. Herbert, Ltd., of Atlas Works, Levenshulme, Manchester, exhibited their well-known file-testing and tool steel testing machines, together with an Olsen universal testing machine of 100,000lbs. capacity. This latter tool makes tensile, compressive, and transverse tests, while automatically weighing the load and drawing a stress strain diagram. An Olsen autographic transverse testing machine was also shown, this being chiefly used for testing cast iron up to 5,000lbs., while recording the results autographically; together with an eccentric saw, in which the angular position of the blade is varied periodically by means of eccentric motion; a rapid saw fitted with mechanism for relieving the pressure on the blade on the back stroke; and a universal filing machine, this latter being a very useful tool for rapidly facing up small castings, forgings, &c., by power filing.

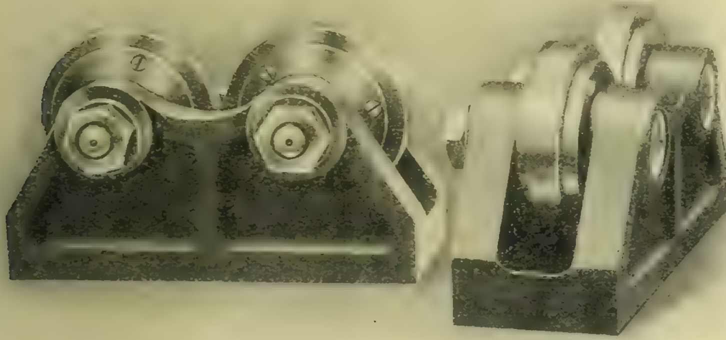


FIG. 1.—BALANCING HEADS. MESSRS. EDWARD G. HERBERT, LTD., MANCHESTER.

Many new and useful devices in the shape of small tools and appliances were also exhibited, and we have pleasure in illustrating and describing a few of these in the present article, while others we hope to describe in a succeeding issue.

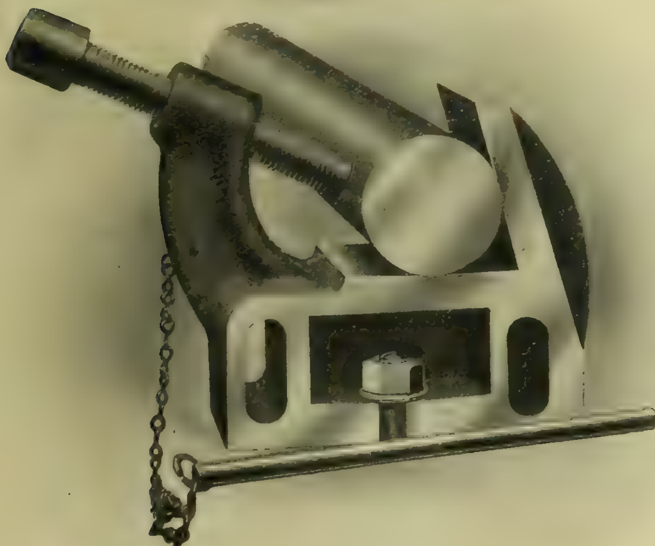


FIG. 2—IMPROVED VEE CRAMP. MESSRS. EDWARD G. HERBERT, LTD., MANCHESTER.

Fig. 1 is an illustration of a pair of balancing heads consisting of discs running on ball bearings. These are intended for balancing on their shafts, armatures, flywheels, pulleys, &c., up to one ton in weight, and are very sensitive. They are superior to straight edges, because they do not need to be perfectly levelled, but can be used on a pair of ordinary shop trestles; also the shaft to be balanced need not be perfectly horizontal, and it may have two diameters.

Another useful device is shown in Figs. 2, 3, and 4, viz., an improved vee cramp for use on drilling, milling, and planing machines.

As will be seen, in addition to its use in place of the ordinary vee blocks this cramp can be turned on its side to hold cylindrical work with its axis vertical. This greatly increases its usefulness on milling and planing machines, and makes it an indispensable adjunct for all drilling machines. Used as a vee block, it has the following advantages: The upper surface of the shaft is exposed, and a keyway can thus be cut along its whole length; shafts can be placed in and removed from the cramp without interfering with the holding-down bolts, ensuring that the shaft shall always come in the same position on the machine; and the shaft rests on a horizontal planed surface, whereby its parallelism is always ensured.

Fig. 5 shows a patent hexagon cramp of Messrs. Herbert's manufacture—a most useful type, as it gives six different heights of packing for each of the six sides of the block. The advantage of this arrangement is obvious. Time is saved which would otherwise be wasted in searching for packing, and the cost of machine work is thus considerably reduced. The cramps also, being of steel, are strong enough to stand the roughest usage.

Fig. 6 illustrates a "sectional" bar rack as made and supplied by the firm. By the use of the sections, it will be seen that any required size of bar rack can be readily built, either with the arms at one side only, to go against a wall, or with double arms as shown in the photo view.

Messrs. The Selson Engineering Company, Ltd., of 85, Queen Victoria Street, London, had a large and interesting exhibit of machine tools, including drillers, lathes, shapers, millers, grinders, tooth-rounding, broaching, and screw-making machines; and from amongst these we select the following described tools for special mention. Considerations of space alone prevent us giving a fuller account of the exhibits on

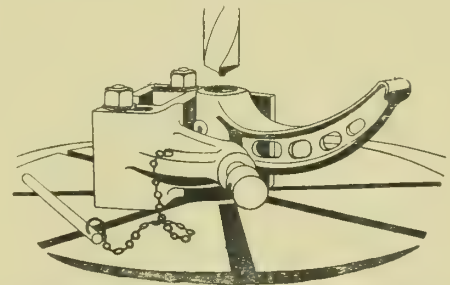


FIG. 3.—VEE CRAMP HOLDING WORK BY THE BOSS. MESSRS. EDWARD G. HERBERT, LTD., MANCHESTER.

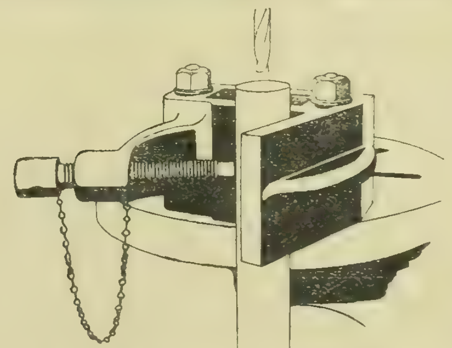


FIG. 4.—VEE CRAMP HOLDING WORK OVERHANGING THE TABLE. MESSRS. EDWARD G. HERBERT, LTD., MANCHESTER.

this stand, as almost every tool shown had distinctive features meriting more than mere passing notice.

Fig. 7 shows a patent special shaping machine shown by the firm having traversing tool-box and adjustable bottom table, whereby large work can be operated on as well as small. This illustration in itself is almost self-explanatory, so we do not purpose taking up much space with a lengthy written description of the tool. We may, however, mention that it has been specially designed for operating on articles too large to be mounted on the ordinary rising and falling table, and, for this purpose, the baseplate is provided with a work table, which has hand lateral adjustment. The head of the ram, as will be noticed, is built in the form of a cross slide, along which the tool slide can traverse automatically or by hand. By combination of the lateral movements of the bottom table and tool slide, work usually done on the planer, such as machining the main bearings of small engine beds, &c., can be performed on this machine. To do this the work is bolted to the bottom table, which is locked to the baseplate, and the first bearing machined with the travelling tool. The table is then adjusted until the second bearing is brought to the position originally occupied by the first, and the machining process repeated. The ordinary rising and falling table is hinged to the cross slide, in order that it may be swung clear of large work without the inconvenience of removal.

Fig. 8 shows a novel design of sensitive drilling machine exhibited. As will be seen, the drill spindle is driven by inverted cones and friction belt, and so the speed of the drill can be increased or decreased at will, as the pointer at

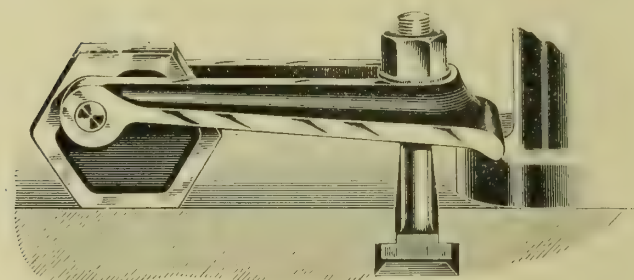


FIG. 5. HEXAGON CRAMP. MESSRS. EDWARD G. HERBERT, LTD., MANCHESTER.

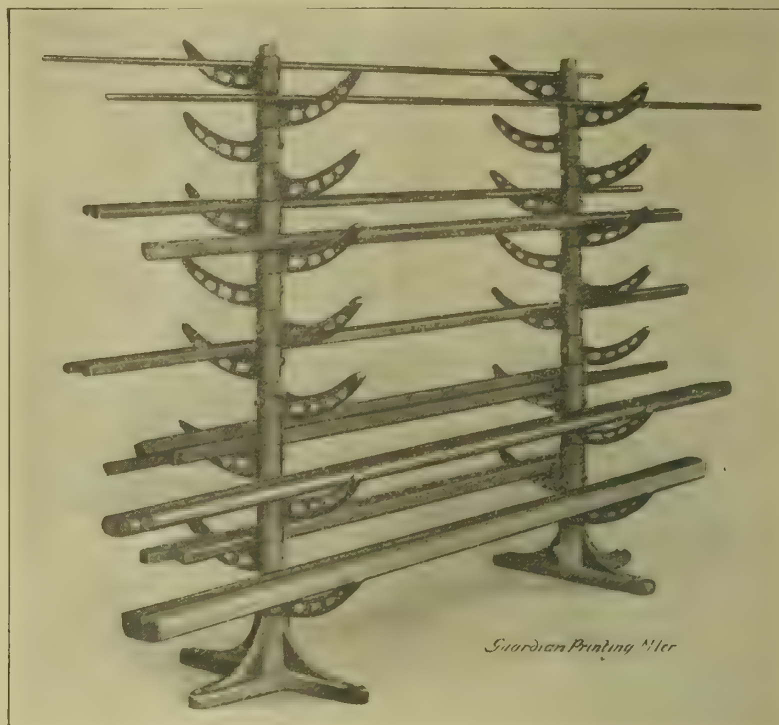


FIG. 6.—"SECTIONAL" BAR RACK. MESSRS. EDWARD G. HERBERT, LTD., MANCHESTER.

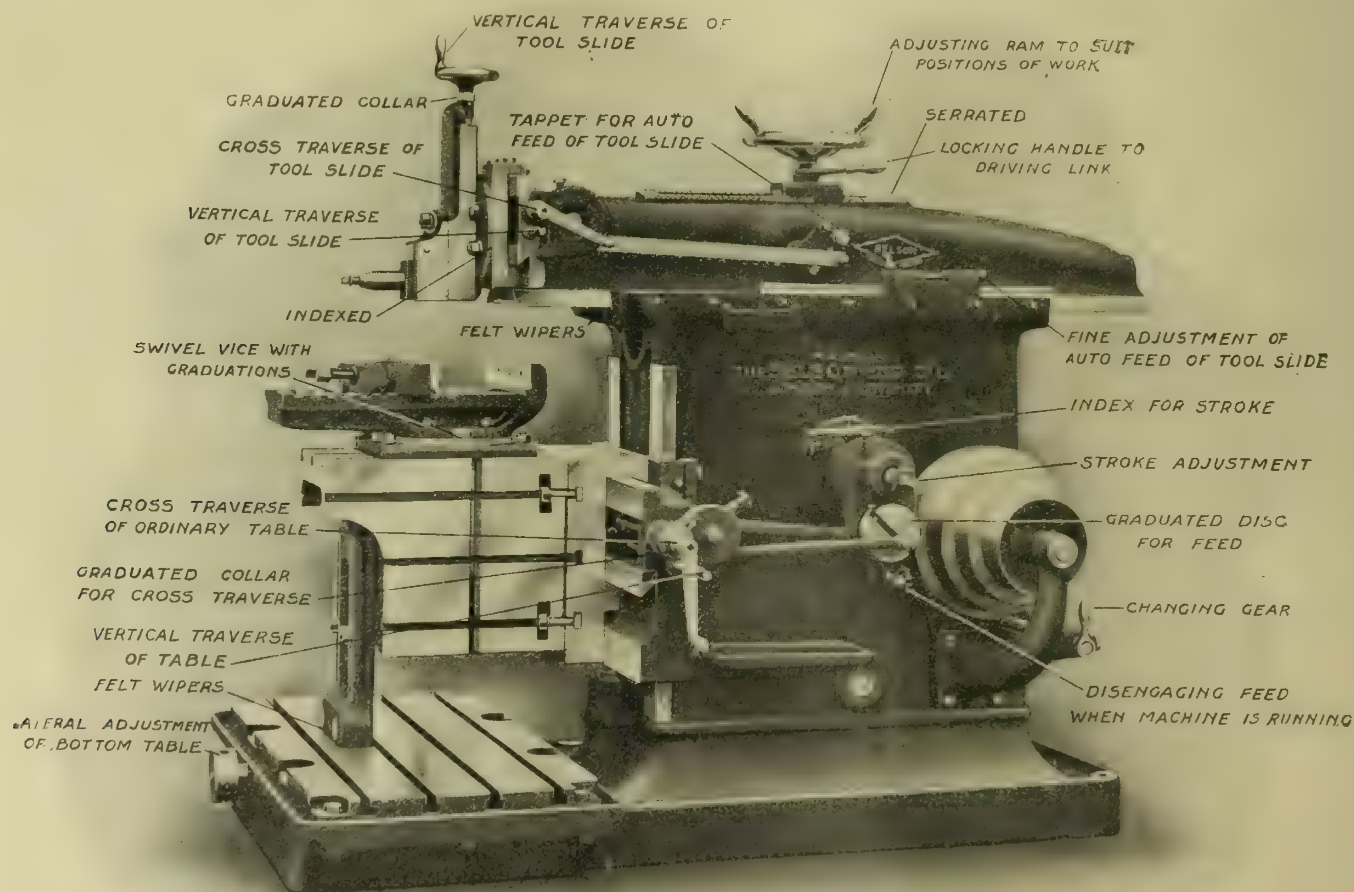


FIG. 7. 25IN. STROKE SPECIAL SHAPING MACHINE. MESSRS. THE SELSON ENGINEERING COMPANY, LTD., LONDON.

the end of the belt shifter is moved up or down on the speed index plate on the side of the frame. This index plate shows the correct speed for all sizes of drills from $\frac{1}{4}$in. to $\frac{7}{8}$in. by sixteenths, and thus there is no excuse for the machine being run at any other speed than that corresponding to the drill being used.

The friction of belt cone can also be varied to suit the size of drill being used, by raising or lowering the lever shown at the back, without stopping the machine. All speeds from 250 to 1,000 revs. per minute are thus available instantly.

Two useful devices are illustrated in Figs. 9 and 10, Fig. 9 being a gravity drilling machine vice, and Fig. 10 a drilling jig.

By slightly turning the handle of the former tool the jaws may be opened on the angle guides, the upper to a maximum of 8in. and the lower to $2\frac{1}{2}$in. When the work is set, gravity, supplemented by the pressure of the drill, forces the jaws downwards in the guides, ensuring an absolutely firm hold of the work and making the vice practically an automatic tool. A slight turn of the handle prevents the work from becoming slack when the pressure on the drill is decreased at the bottom of the hole.

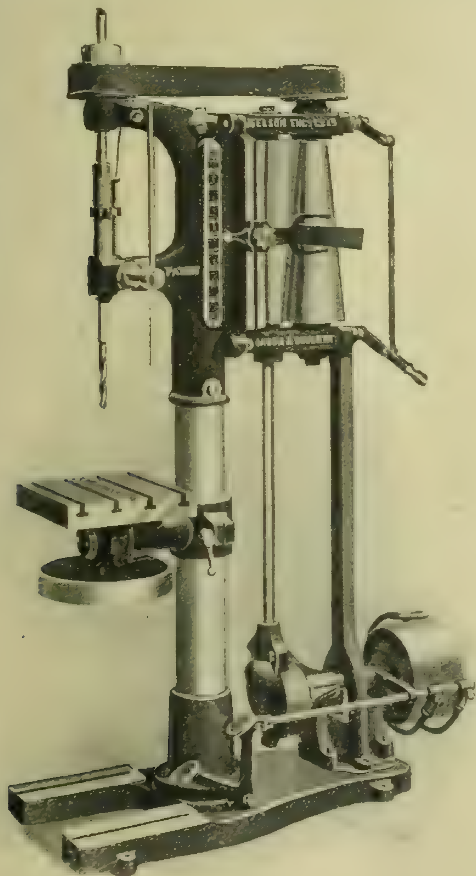


FIG. 8.—PATENT "QUICK CHANGE SPEED" SENSITIVE DRILLING MACHINE. MESSRS. THE SELSON ENGINEERING COMPANY, LTD., LONDON.

The vice can be used loose on the machine table, except in extreme cases. Slots are, however, provided for bolting it down, although same are not shown in illustration. It will securely hold all round work from $\frac{1}{2}$in. to 8in. diam., and work is ensured against turning even with only a slight pressure on the drill.

The drilling jig has been designed for drilling pinholes in bolts, studs, pins, &c., and for this class of work dispenses entirely with the necessity of marking off. As will be seen, it consists of a baseplate, on which are mounted two pillars carrying, at the top, a steel cross-beam, which serves as a clamp for holding the work and also as a guide to the drill by means of suitable bushes. The jig can either be used on a table with a plain surface or bolted down, as required. For plain-surface tables, a locating pin is supplied to fit the baseplate and hole in the centre of drilling machine table, keeping the guide bush in cross beam always in line with the drill spindle.

The work is held in a vee block, provided with a groove on each side, fitting the square portions of the pillars, which thus act as guides, enabling the block to be rapidly adjusted to the required position indicated by pointer and rule, and

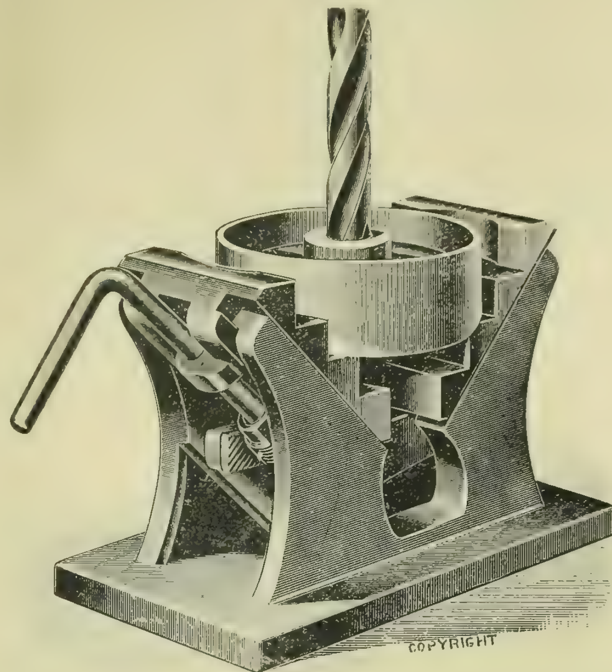


FIG. 9. "GRAVITY" DRILLING MACHINE VICE. MESSRS. THE SELSON ENGINEERING COMPANY, LTD., LONDON.

afterwards locked in place by a small lever instead of the hexagon nut shown in illustration. This block admits bolts from $1\frac{1}{2}$in. to $\frac{3}{4}$in. diam., and for smaller work an additional vee block is supplied, which fits into the larger one, and can be used for objects down to $\frac{1}{4}$in. diam. For studs and other parallel work, stops are provided on the right of both vee blocks, against which the end of the stud rests.

Amongst the small tools shown, mention may be made of a novel design of "He" templet gauge which is greatly tapered at the very end; then there is a short length very finely tapered, revealing another thousandth to come off the work, and finally the gauge becomes dead size. Such gauges are very useful, as they enable the end to be pointed in, and the operator can thus judge when he is approaching the correct finished size of hole.

Messrs. Kynoch, Ltd., of Lion Works, Witton, Birmingham, exhibited one of their well-known gas engines of 100 b.h.p.

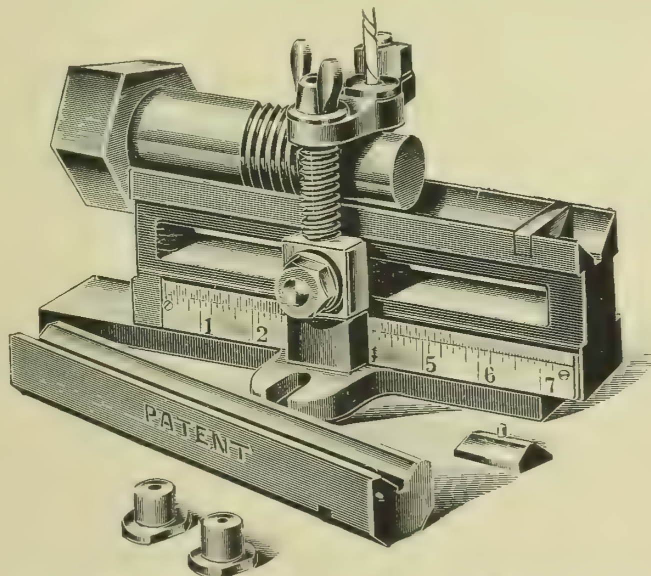


FIG. 10. "SELSON" QUICK-CHANGE UNIVERSAL DRILL JIG WITH TOP V BLOCK REMOVED FOR DRILLING LARGE BOLTS. MESSRS. THE SELSON ENGINEERING COMPANY, LTD., LONDON.

This engine was shown working with gas supplied from one of their patent suction plants, also erected on the stand.

Another exhibit of the firm was the Kynoch patent dust-

proof and self-oiling roller bearing, two illustrations of which we have pleasure in giving, Fig. 11 showing the complete bearing and Fig. 12 same with cap removed. On the stand lengths of shafting were shown running in this type of bearing, together with others running in plain bearings, and so fitted that the amount of friction in each case could be understood at a glance. The coefficients of friction of repose and of motion of the Kynoch roller bearing are, the firm state, ·0115 and ·0082 respectively, or about $\frac{1}{10}$th of the coefficient of friction of an ordinary bearing in each case. It will thus be seen that a considerable saving of power results from their adoption.

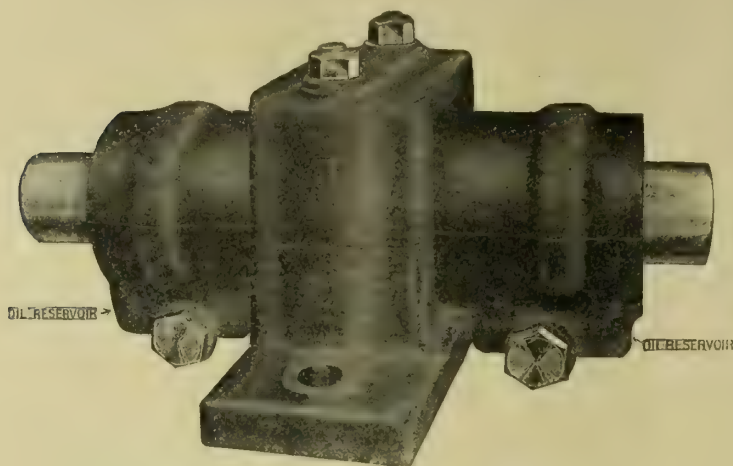


FIG. 11.—COMPLETE KYNOCH ROLLER BEARING. MESSRS. KYNOCH, LTD., BIRMINGHAM.

Messrs. George H. Alexander, of Doe Street, Birmingham, exhibited a large collection of machine tools, principally of the fully automatic kind, and from amongst these we take pleasure in illustrating and describing two at length. Some 18 machines were shown altogether, so it becomes impossible for us to more than mention most of them. They included drilling machines of several types and sizes, plain, surface, and universal grinders, fully automatic pin and stud machines (Models "D," "F," "G," and "H"), wood screw worming, shaving, and slotting machines, heading, screw-threading, and pointing machines, and a four-spindle boring machine. The ones we illustrate are Fig. 13, a three-operation automatic screw machine, and Fig. 14, an automatic screw slotter.

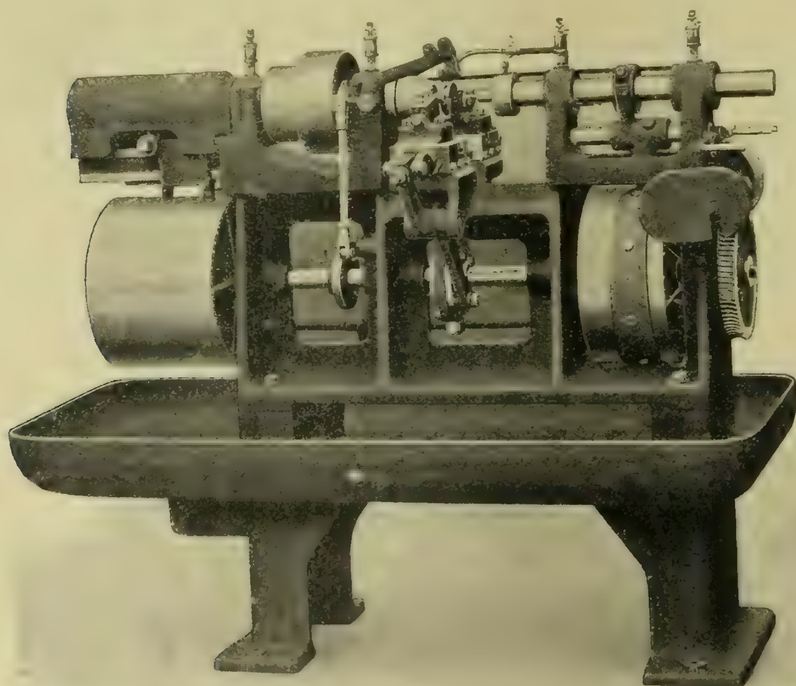


FIG. 13. THREE-OPERATION AUTOMATIC SCREW MACHINE. MESSRS. GEORGE H. ALEXANDER, LONDON.

Three-operation automatic screw machines, or pin and stud machines, as they are sometimes termed, are deservedly popular and widely used on account of simplicity of design and ease of operation. The type is fully automatic, as the operator has nothing to do but insert the bar in the feeding mechanism, remove the finished product and swarf from the pan of the machine, and keep the simple tools with which they are equipped in order. A successful operator can run with the aid of a boy as many as 20 of these machines on certain work, providing the pace is not set too high, but many manufacturers prefer a moderate pace with long life to the tools, and a large number of machines per operator as being more economical than high speeds, with the consequent repeated tool grindings, with the time lost in stopping, and the extra number of operators required. Thus, for instance, some manufacturers of bicycle chain will run as high as 20 finished chain rolls per minute, whilst others prefer a running speed of 12. In any event, the speed at which a piece can be produced on this machine is entirely within the will of the manufacturer up to the maximum limit which is possible for drilling, forming, and cutting off. The machine itself is constructed sufficiently well so that the headstock can be driven at the maximum speed, and the rigidity of the machine due to the proper proportion of its component parts is such that it will stand any strain which can be put upon it.



FIG. 12 KYNOCH ROLLER BEARING WITH TOP CAP REMOVED SHOWING STEEL ROLLERS ON WHICH THE SHAFT REVOLVES. MESSRS. KYNOCH LTD., BIRMINGHAM.

Any piece within the capacity of the wire feed can be made on the machine, which does not call for more than three operations, and work which needs more than three operations can oftentimes be done to advantage on the machine under notice, as the secondary operations can be cheaply done elsewhere, such, for instance, as nuts and cones, which are blanked on this machine and automatically tapped on nut-tapping machines; bolts, screws, and studs, having threads which are blanked first and subsequently threaded in a screw-threader, or a bolt-cutter. For plain or taper pins, balls, washers, rollers, and such like pieces the machine is, however, perfectly adapted.

The cross slide of the machine we illustrate is in two pieces, and these can be operated independently or simultaneously—a time-saving feature which will be appreciated when forming and parting off can be done at the same time. It is also fitted with fine adjustment for forming to exact diameter, with positive drawback on cams in all sizes above ½in. wire feed. The cam drum actuating the cross slides on all sizes excepting their Model "D" is in two halves to facilitate the fitting of cams, and the machine is fitted with an efficient stop for feeding to dead length. Five changes of feed through gearing are regularly supplied, and an efficient oil pump is fitted to each machine. The tailstock can, we are informed, be supplied either fixed, or rotating when deep hole drilling is required, and when fitted with revolving spindle the belt pull is taken on the main frame casting, and not on the spindles.

The automatic screw slotter shown in Fig. 14 embodies

many new and valuable features. The most noteworthy of these are that the screw blank is rigidly held while the slotting takes place; sensitive adjustment is provided to accurately locate the position of the saw with respect to the screw head; the saw is well guarded, and this guard can be quickly swung out of the way to change saws; when the saws are changed the saw spindle is held from revolving when the clamping nut is being loosened by a pin which is temporarily inserted into the driving gear disc; and provision is made to allow the machines to operate at the speed which is most suitable for the particular screw to be slotted—the power for driving the saw being obtained through a belt from a countershaft to a pulley which is back geared to the saw spindle. The gearing is so arranged that by merely reversing its position on the saw spindle a suitable speed is obtained for both steel as well as brasswork, thus leaving the pulley always in the same position.

In the operation of the machines the blanks are placed in the hopper, where they are caught by their heads in a blade which has a slot along its top a little wider than the

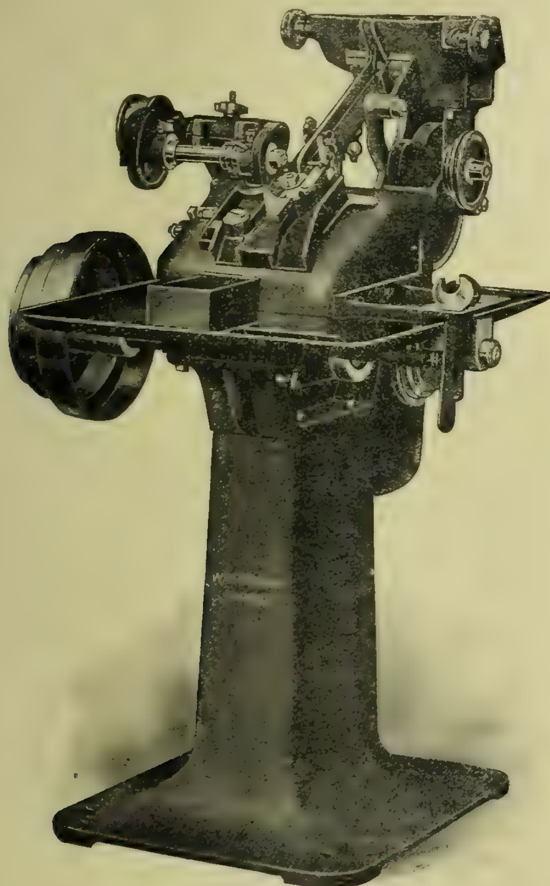


Fig. 14.—Automatic Screw Slotter. Messrs. George H. Alexander, London.

body of the blank. The blade swings vertically through the centre of the hopper, and when in its lower position is parallel with the bottom. As it is elevated through the mass of blanks some get caught by their heads and carried to the upper position, which is an extension of the inclined chute. Here the blanks slide into the chute. Near the point where they leave the blade is a rapidly revolving toothed wheel, located and adjusted so that any blanks which attempt to enter the chute excepting in the proper position are thrown back into the hopper. This leaves the entrance to the chute clear and prevents clogging.

The chute covers are hinged so that they can be swung up for removing any blanks that may become lodged. At the foot of the chute the blanks enter the small carrying dial. If a blank becomes held half in the dial and half in the chute a slight special motion which is given to the dial agitates the column of blanks and starts the feed after the loss of only one revolution of the machine, and entirely without the attention of the operator The carrying dial has " V " notches in its periphery which carry the blanks from the chute to the slotting point. After being slotted the blanks are carried a little further and delivered into their receptacle.

Messrs. The Bosch Magneto Company, Ltd., of 40-42, Newman Street, Oxford Street, London, W., exhibited several types, both high and low tension, of their well-known magnetos and high-tension sparking plugs, together with a new type of mechanical force-feed lubricator for the automatic lubrica-

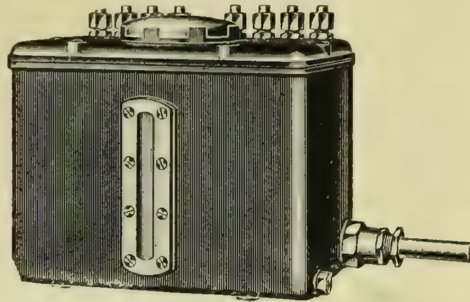


Fig. 15. Bosch Lubricator. Messrs. The Bosch Magneto Company, Ltd., London

tion of all types of engines, machine tools, &c. Various patterns specially designed for use with Diesel and similar type engines were shown, together with locomotive lubricators, &c. One of these lubricators, known as Type " A," we have pleasure in illustrating in Fig. 15, and this view, together with the diagrammatic illustrations given in Fig. 16 and the

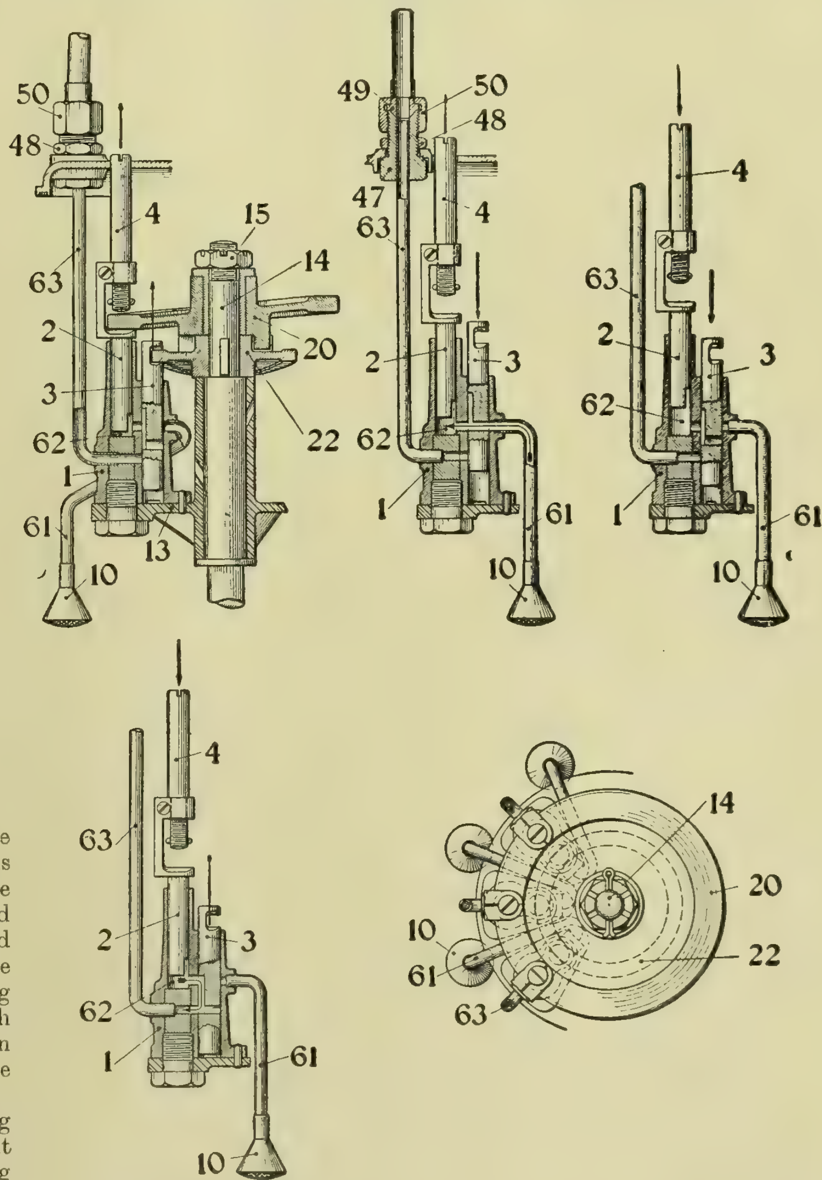


Fig. 16.—Diagrammatic View showing Working of Type " A " Bosch Lubricator. Messrs. The Bosch Magneto Company, Ltd., London.

following short description, will enable its general design and working to be understood.

In this lubricator the oil is taken from the tank by a number of separate pumps arranged in a circle around the common shaft, and is delivered to the various points of lubrication through suitably arranged tubes. The various

parts of the pump, consisting of the pump body, the valve piston, and the pump piston, are mounted on a baseplate, so that all the valve pistons are concentric to the pump pistons and are operated within cylindrical chambers bored in the pump castings. The common drive of the valve and pump

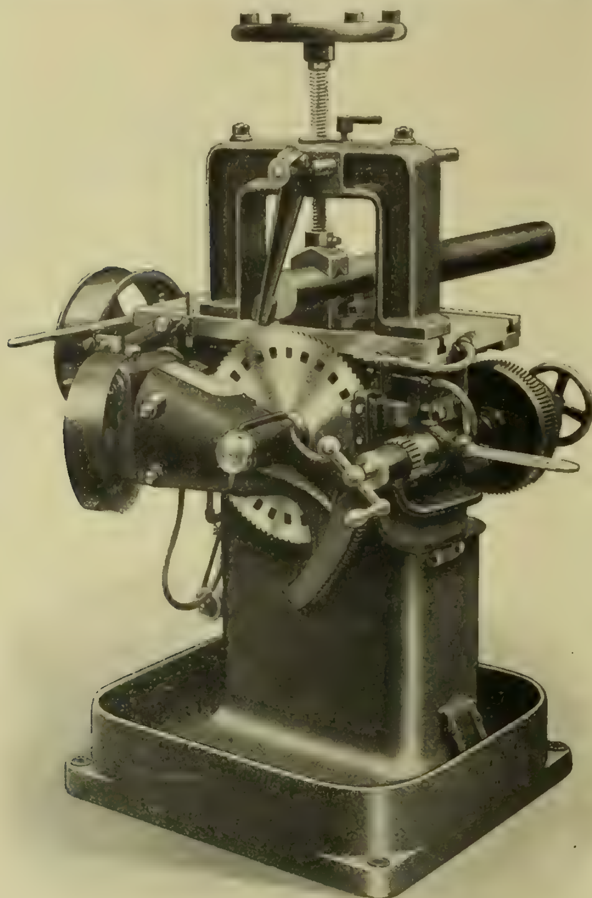


FIG. 17. HIGH-SPEED COLD SAWING MACHINE. MESSRS. F. M. FRYE & CO., LONDON.

pistons is from two helical wheels, the pump wheel and the valve piston wheel, the rims of which are guided in the crank-shaped heads of the pistons. These two operating wheels are set at an angle to the vertical pump shaft, and are arranged to each other so that the wheel working the valve pistons begins to operate 90° earlier than the wheel which works the pump pistons. The pump wheel is fitted loose on the shaft and is carried round by a peg engaging in a slot which is made in the valve piston wheel, the latter being fixed on to the driving shaft. This arrangement enables the lubricator to be rotated in either direction, without any special alteration. When the direction of rotation is changed, only the wheel rotates at first, until the end of the slot cut in its boss engages with the peg of the wheel, when both wheels move together again, the wheel operating the valve pistons having, as before, the necessary lead of 90°.

Adjusting screws are fitted in the crank-shaped heads of the pump pistons, by means of which the amount of the dead movement of the operating wheel can be altered. These adjusting screws reach through the cover of the casing, and are protected by a nut which also covers the opening of the lubricator casing. The opening is enclosed by a removable filter which collects foreign substances from the oil that might injure the pumping mechanism.

A pinion is mounted on the pump shaft, and is rotated by a worm which is mounted on the driving shaft. This latter projects through the lubricator casing, and is coupled to the driving shaft of the machine. The base of the pump is fixed to the oil-box cover by means of three bolts, so that it is possible after removing the cover to take the complete pumping mechanism from the lubricator box. In order that the oil level may be seen without removing the nut, an inspection window, as shown in Fig. 15, is arranged in the front of the lubricator box.

The Bosch lubricator works as follows: The pump shaft 14 (see Fig. 16) is rotated by means of a worm and pinion as soon as the machine is put in motion. The two helical wheels 20 and 22 rotate with the pump shaft and operate the pistons as a result of the rims of the wheels running in the guides of the piston heads and forcing the latter to move up and down. The various valve and pump pistons do not all work simultaneously, but successively in accordance with the setting of the helical wheels, which, as already described, are so set to one another that the valve pistons always begin to operate 90° before the pump pistons.

The left-hand top illustration of Fig. 16 shows the position of the various parts. The pump piston 2 has just reached its lower dead centre, and is at the beginning of its suction stroke when the corresponding valve piston 3 is half-way up. When the pump shaft 14 is rotated (in this figure right-hand rotation is presumed) the valve piston 3 continues on its upward stroke, and so establishes a connection between the suction 61 and the pump base 62, as is clearly shown in the middle top figure. Continuing the movement of the pump shaft 14, the pump piston 2 moves upwards, thereby drawing the oil through the suction channel 61 into the pump base 62. When piston 2 has reached the upper end of its stroke, as shown in the right-hand top illustration, the valve piston 3 will have closed the suction tube 61 again. The valve piston 3 continues its movement downwards and forms a passage between the pump space 62 and pressure connection 63, so that under the pressure stroke of the pump piston 2 the oil in the pump space 62 is forced in the direction of the arrow (bottom left-hand illustration) into the pipe 63. When the pump piston 2 has again reached the lower end of its stroke all the parts will be in the position shown in the first-mentioned view, and the previous sequence of operations will once more be repeated.

As the movement of the pump and valve pistons depends on the position of the two helical wheels, the sequence of operations just described is repeated successively on all the pumps arranged round the pump shaft 14 (see the right-hand bottom view).

Messrs. F. M. Frye & Co., of 46, Upper Thames Street, London, E., had an interesting exhibit of machine tools, including shapers, high-speed cold sawing machines, lathes, drilling machines, and chucks. From amongst these we select the three following tools for special mention, and supplement this with a short description of several of the other tools shown.

Fig. 17 is an illustration of a high-speed cold sawing machine shown by the firm. Great advancement has been made during the last few years in the capacity of this class

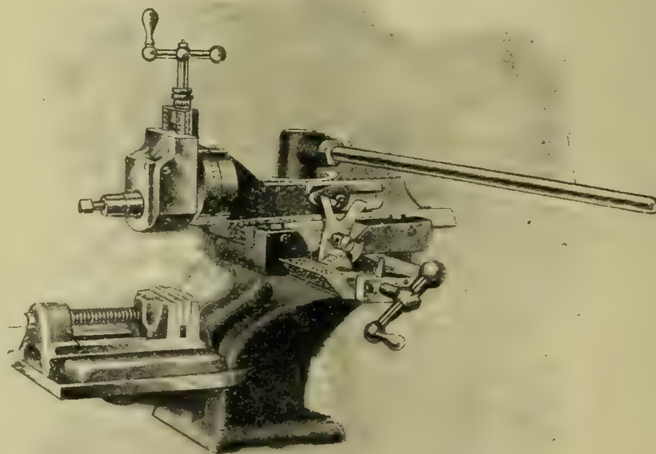


FIG. 18. HAND SHAPER. MESSRS. F. M. FRYE & CO., LONDON.

of tool, and the machine exhibited was one of the latest productions on the market. As showing its capabilities, we may mention that at the exhibition one of the machines was shown at work cutting through Bessemer steel bar 3¼in. diam. in under 3 mins. The drive of the saw is not from

the centre, as usual, but by means of a gear which engages in slits near the circumference of the saw blade, these slits being clearly shown in the illustration. By this means any tendency to bend and break the saw blade is avoided, and the utmost capacity of the saw can be drawn upon. Friction



Fig. 19.—Sensitive Drilling Machine. Messrs. F. M. Frye & Co., London.

feed, operated from the side of the machine, is adopted, and this feature prevents the sawings and lubricant from getting into the working parts; and, by means of the special spindle which operates the feed, any feed can be obtained while the machine is in motion. A pump is fitted to give sufficient lubricant and cooling fluid to the saw blades whilst at work, this lubricant flowing back automatically after use into the stand of the machine, which serves as a tank.

Shapers were represented by a small hand machine, which we have pleasure in illustrating in Fig. 18, and one of the largest sizes, 18in. stroke machines. They are, Messrs. Frye and Co. state, manufactured by the largest works in the whole of Europe, making this class of tool a speciality, viz., Messrs. Wotan-Werke, Aktiengesellschaft. The general design of the hand shaper will be understood from the illustration of it we give. As will be seen, the head can be set at any angle, so that sloping key-seats, &c., can readily be produced, self-acting surfacing motion being also fitted, giving slow or rapid traverse to the tool as desired.

Fig. 19 shows one of the firm's sensitive drilling machines, the main features of which will also be gathered by a glance at the illustration. This has been designed for drilling holes up to ½in. diam., and, as shown, is fitted with a sliding headstock. Lathes were represented by a 6in. centre "I.X.L." machine, fitted with capstan head; one of the rapid reduction type; and a third, a treadle machine of 5in. centre. This latter lathe is a well-made tool, having gap bed, and capable of doing surfacing, sliding, and screw-cutting. Independent, combination, geared scroll lathe chucks, and two and three-jawed drill chucks, were also to be seen on the stand in many sizes. Messrs. Frye & Co., we may mention in conclusion, only supply customers through local engineers' factors.

Messrs. Humpage, Thompson, & Hardy, of Jacob Street, Bristol, exhibited gear-hobbing machines, a class of tool they make in large quantities; high-speed hack-saws; hack-saw sharpeners; and lathe-centre grinders, many of which were shown in operation.

Three sizes of high-speed gear-hobbing machine were on view, viz., a 32in., 22in., and 16in., the two latter being shown at work. These machines, we noticed, were exceptionally stiffly built, so that they are capable of taking heavy cuts without chatter; and the speed and feed changes are also extremely easy to operate. All were self-contained, no countershaft thus being required, and any may be electrically driven by motor mounted on the column. As showing their capacity, we may mention that on the 32in. machine a steel wheel 31in. diam. and 4in. face may be cut with 60 teeth, 2 D.P. (1½in. circular), from the solid blank in 5 hours. This machine will, however, cut wheels up to 11in. face.

The second size mentioned was fitted with spiral cutting attachment, and was suitable for hobbing spur and worm wheels up to 22in. diam. by 9in. face, by 4 diametral pitch in steel, and spiral wheels of specified leads. The spirals are cut from formers, and thus no mathematical knowledge on the part of the operator is required. The machine has been specially designed for the use of gas-engine makers and others who have much repetition work on standard spirals.

The 16in. machine was capable of hobbing spur and worm wheels up to 16in. diam. by 9in. face by 4 diametral pitch in steel, and can, we understand, be fitted with the spiral cutting attachment mentioned above when desired.

The hack-saws shown by the firm were fitted with an ingenious device by means of which the pressure on the saw blades could be regulated and remain constant till they were nearly through the work, when the saws were relieved automatically of nearly all the pressure. A rocking motion was also given, and on the return stroke the saws were automatically lifted. Patent roller steadies compel the blades to move in a truly vertical plane, and, as showing the efficacy of these, some sections of steel $\frac{1}{16}$in. thick, cut from a 6in. bar in 19 mins. each, were also shown.

The lathe centre grinder shown by the firm we have pleasure in illustrating in Figs. 20 and 21. This is a handy and very useful tool, as by its means not only can lathe centres be accurately and quickly ground, but internal and

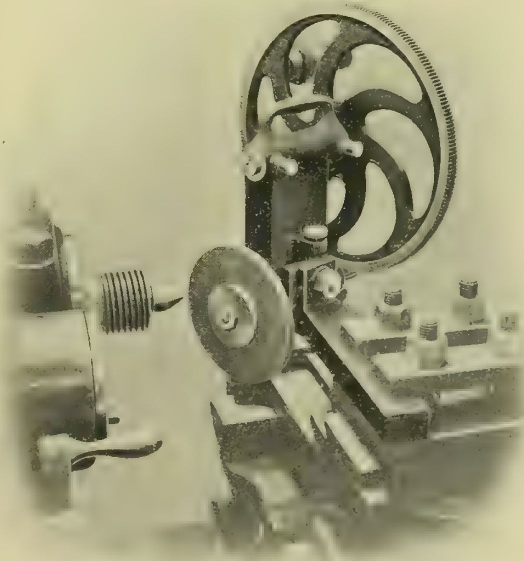


Fig. 20.—Lathe Centre Grinder. Messrs. Humpage, Thompson, & Hardy, Bristol.

external parallel grinding may also be accomplished on small work by its aid.

Fig. 20 shows the device fitted to the tool-holder of a lathe, and in position for centre grinding. It is, as will be seen, operated by hand, and when so fixed automatically

reciprocates to and fro across the face of the centre to be ground. This reciprocating motion is imparted by means of a lever, operated by a worm wheel which is fixed in the recess at the back of the box-shaped upright casting, and which in turn is driven from a worm on the handwheel



Fig. 21. Lathe Centre Grinder, fitted with internal grinding attachment Messrs. Humpage, Thompson, & Hardy, Bristol.

shaft. The travel of the wheel obtained by this means is 1in. When fitted with the attachment shown in Fig. 21 the tool may, as mentioned above, be used for internal grinding, provided the face to be ground be not more than 2in. in length, and not less than ¾in. bore. The attachment is fixed in position by slacking back a clamping nut, slipping the forked arm of the internal grinder under the nut, and tightening up. When the wheel is not desired to reciprocate, the cover is moved aside at the back, and a screw taken out of the worm wheel and inserted in another hole. The spindle is speeded up by means of a pair of bevel wheels, the larger of which screws on to the periphery of the nut-plate holding the 4in. grinding wheel in position, the nut-plate having a thread cut on it for the purpose. The larger bevel wheel is thus screwed up against the large grinding wheel, and this arrangement avoids dismantling the grinder for conversion from one form to the other. It is, of course, not intended that this attachment should be regarded as a substitute for an internal-grinding machine, but as a convenience when such a machine is not available.

Messrs. The Leeds Meter Company, Ltd., of Tower Works, Armley, Leeds, had an interesting and instructive exhibit of meters for measuring water flow in pipes. These were shown in great variety, both in the form of complete meters, and as sectional models, the latter enabling the construction and working of the meters to be readily understood. Both dry rotary, wet rotary, and dry disc types were on view, with their respective sectional models, and ranging in size from ¾in. to 5in., as well as the firm's Helix meter, which latter we have pleasure in illustrating in Figs. 22 and 23, and in describing at length below. This meter is especially adapted for registering big flows, and metering large mains, a duty which, up to now, has been performed almost exclusively by instruments which register the deviations and the velocity of the water, or a factor corresponding to the same. With the meter under notice, however, the quantity of water passing through it is not calculated from a velocity diagram, as is the case in all other types of meters used for the same purpose, but is registered directly on the dial, and when required, this registration can be transmitted from the dial to a diagram, either by mechanical or electrical means. In the latter case the diagram may be placed at any distance from the meter itself.

The construction of the Helix meter is founded on the principle of the old type fan current meter, used for determining the velocity of water in open channels, the instrument for measuring being a propeller with helical screw-shaped vanes. This measures the actual velocity of the flow of water impinging on the face of the helical vanes, and this actual velocity multiplied by the sectional area of the mains, less the sectional area of the helical vanes, gives the actual delivery of water. This is the theory on which the delivery of the Helix meter is calculated.

Conditional to there being an absence of friction, and also to the helical vane being exactly screw shaped, by each revolution of the helical vane the length of the water stream passing is equal to the pitch of the screw. Supposing, therefore, P to be the pitch of the screw-blades, R the number of revolutions, A the sectional area of the pipe less the sectional area of the helical vane, and D the delivery: Then the delivery per revolution of the vane is: $D = A \cdot P$ and at R revolutions $D = R \cdot A \cdot P$.

At any velocity of water this proportion is, of course, constant, and A and P being constant for any size of water meter, D is exactly proportional to R, and it is proved that the revolutions of the helical vane, and therefore the registration of the meter, increase proportionally with the increase of velocity of the water flow.

It is well known that the average velocity of water flow in a plain closed pipe or conduit takes place between the circumference and the centre of the pipe, that is, at a point between the maximum velocity at the centre, and the minimum velocity at the circumference where the friction is. When helical vanes are fitted to a section of the pipe, as becomes the case when the meter under notice is fitted, there are two points of average velocity, and the problem becomes to construct a helix so that these two points fall on the blades. This the Leeds Meter Company claim to have done. Furthermore, as the vane is of very light material (celluloid), and provided with a hollow cylinder, a certain buoyancy is acquired, and as it is entirely submerged and therefore may be considered weightless, as far as pressure on its bearings is concerned, immediately on the cessation of the flow of water in the pipe the momentum of the vane is overcome, and the meter stops running. Another advantage of the light construction, as pointed out above, is that the whole weight of the helical vane is taken off the bearings, and the running is essentially without friction. Supposing a heavier or metal vane were to be employed, then the number of revolutions would be more or less behind the velocity of water, and in order to determine the quantity of flow this fact would have

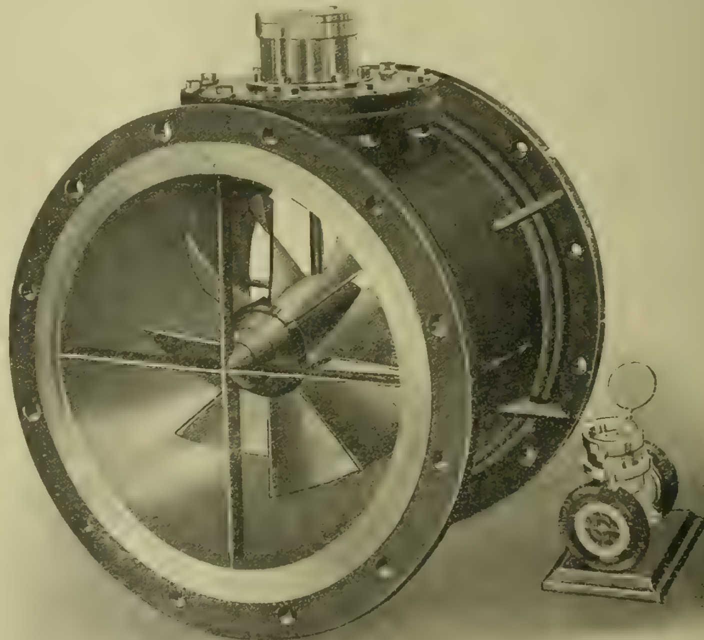


Fig. 22. The Helix Meter. Messrs. The Leeds Meter Company, Ltd., Leeds

to be taken into consideration. It is only through rendering the vane weightless in water, that the Helix meter has become applicable in practice.

The meter, as will be seen by a reference to the illustrations we give, is provided with a dial gear placed directly on the

top, allowing convenient reading of the quantity of water passing through; and, for the observation of the water consumption, which is the general object of the use of water meters, this is the best and simplest form.

A simple regulation contrivance is also fitted by means of which any errors within the limits of $\pm$ 10 per cent. can be corrected. This consists of a movable plate regulated from the outside of the meter, which when not in use is covered with a cap, fastened with a lead seal, to prevent it being tampered with.

During the last few years, we understand the adoption of the Helix meter has very rapidly increased, and several thousands of this type are now in use in water mains, varying from 2in. up to 48in. diam.

The firm are to be complimented on the excellence of their exhibit, and no less on the workmanship displayed in their finished products.

Messrs. Kater & Ankersmit, of 34, Fenchurch Street, London, E.C., exhibited their new "universal" patent Massip system oil separator and steam dryer; a model of their "Hamon" wooden chimney type water-cooling tower; a patent air-pressure recorder, for automatically recording the draught in boiler furnaces; and a "universal" patent auto. boiler feeder, for automatically maintaining the water in steam boilers at normal level. This latter we have pleasure in illustrating herewith (see Fig. 24), and in describing at length.

The essential parts of the apparatus are composed of the open float T and a balance weight K, which between them control the feed valve V through the levers shown, the whole being actuated by the water level in the boiler. When the water level falls below the orifice of the tube E, the water surrounding the float T runs into the boiler and is replaced by steam. The float therefore loses its equilibrium, overcomes the balance weight K, and in falling opens the feed valve V and the boiler receives water. When the level of the water seals the orifice of the tube E, the steam in the vessel G and the connecting pipe L condenses, and water is again drawn up into the vessel G by the vacuum thus formed; the float T returns to equilibrium, and by the help of the balance weight K, the feed valve V is closed, and the water supply to the boiler ceases until the cycle commences again. The auto. feeder can be put out of action by simply turning the balance weight K over on its hinge, as shown in the illustration, when the boiler can be fed in the usual way without its aid.

With an automatic boiler feeder, such as described, it will be seen that the stoker, being absolved from the duty of regulating the feed, can give more attention to the firing; priming is also minimised, and the plates are prevented from risk of overheating. The firm undertake to supply them on approval on the understanding that they are paid for after one month's satisfactory working, failing which they may be returned to them without payment.

The automatic air recorder mentioned above depends for its action on the loss of pressure of the air due to its passage through the fire. This loss of pressure is directly proportional to the quantity of air passing, and thus a measure of the air supply is obtained as accurate, it is claimed, as that found by an analysis of the flue gases.

Messrs. Cunliffe & Croom, Ltd., of Broughton Ironworks, Manchester, exhibited a collection of machine tools of their manufacture, including milling, planing, boring, drilling, and gear generating machines, many of which were shown in operation, as well as numerous small tools, vices, dividing chucks, &c.

Milling machines were represented by one of the firm's plain horizontal type, having a capacity of 21in. by 6½in. by 16½in.; and a latest pattern vertical 3-spindle planer type, admitting work 6ft. long by 2ft. 6in. between the uprights. This latter machine was specially adapted for the use of motor manufacturers for machining cylinders, crank cases, gear boxes, &c., as well as for general engineering work.

Double-power gearing was provided on the headstock, and the machine was furnished with a cone drive. Single pulley and gear-box drive can, however, be fitted, and with either system 12 spindle speeds are obtainable. The spindle headstock of this type of machine is provided with a power-feed motion along the cross slide in either direction, and automatic trip motions, while the table has eight geared feeds with reverse and quick-return motions in either direction along the bed, with automatic trip. All levers and handles are conveniently situated at one side of the machine, and the elevating screws for the cross slide, and the feed nut under the table are provided with ball thrust bearings.

Two sizes of the company's upright drilling machines were shown, viz., the 20in. and 24in. swing, the first-mentioned being capable of drilling 1¼in. and the latter 1½in. from the solid. A new type of radial drilling and tapping machine was also shown, capable of drilling 1¼in. diameter. This was entirely self-contained, fast and loose pulleys being provided on the base, fitted with foot-operated belt shifting gear. Eight spindle speeds were provided, and a reverse motion for tapping was also fitted on the saddle, which could be instantly operated by lever without shock or jar. The machine was furnished with sensitive hand lever, and worm and wheel feed, with quick return of spindle by hand wheel. The machine exhibited had also the addition of a power-feed motion giving three rates of feed.

Gear generating machines were represented by the firm's No. 1 size, capable of cutting wheels up to 18in. in diameter, and having a maximum width of tooth of 4½in. This was

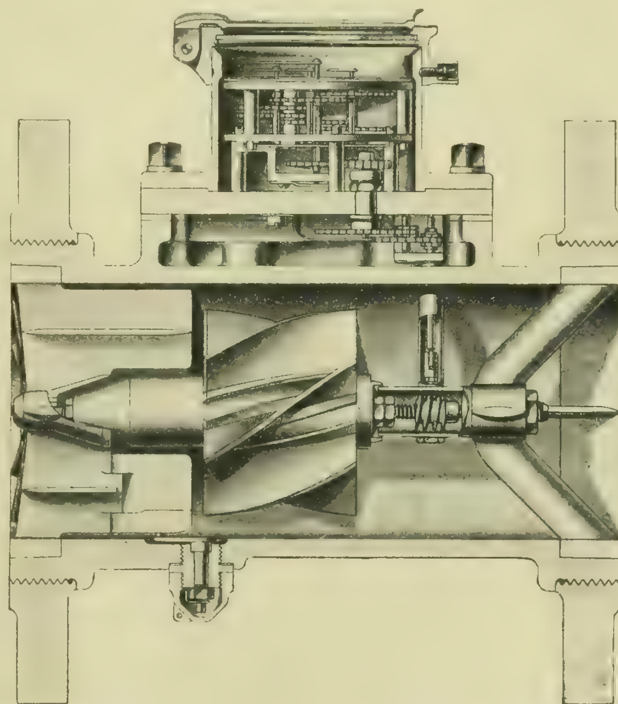


FIG. 23. LONGITUDINAL SECTION OF THE HELIX METER, SHOWING DIAL GEAR. MESSRS. THE LEEDS METER COMPANY, LTD., LEEDS.

shown in operation, being fitted with a temporary electric drive. Ordinarily the machine is driven by means of a three-speed cone from a countershaft, this being the only belt used.

The vertical feed is obtained through a change speed box having four rates of feed operated by a lever, whilst an automatic stop motion is provided, and a graduated hand adjustment is fitted, operated by a hand-wheel at the top of the column. The swivelling motion to the cutter headstock is also operated by a hand-wheel, whereby fine adjustments can be quickly made. An improved steady is a feature of the machine. This supports the upper end of the work mandril, and by loosening a bolt the arms may be swung clear from the work, thus simplifying the process of setting up the gear blanks. The bed is fitted with a suds tray, and is mounted upon cabinet standards, one of which forms a tank for the cutting lubricant, while the other is used as a cupboard for wheels, &c.

Messrs. J. B. Stone & Co., of 135, Finsbury Pavement, London, E.C., exhibited their now well known "Alligator" steel belt lacing, an illustration of which we have pleasure in giving in Fig. 25. This forms a thoroughly satisfactory and efficient method of lacing all kinds of machinery belting. No tool is required but a hammer, it is alike on both sides, the

belt runs smoothly either under or over, and a 4in. belt can, we understand, be laced in four minutes.

As will be seen by a reference to the illustration, the teeth on each side of the lacing enter the belt on different lines of perforation; each prong has two teeth, the longer clinching through the belt, the shorter point on opposite side of prong giving great additional strength. Both enter the belt so that the pull is against the edge of the steel and not against the flat, which, it is claimed, avoids weakening the belt, and, in rubber and textile belts, does not cut the long threads in which lie the strength of that class of belting. Being separable, also, this lacing is especially adapted for use on overhead belts, as the ends can be dropped down, the lacing applied and hinge pin inserted, after which the belt is returned to the shafting. By taking out pin, the belt may be temporarily removed from service, lengthened by inserting a stub section of belting, or shortened by cutting off the excess from one end, and using half of a new lacing.

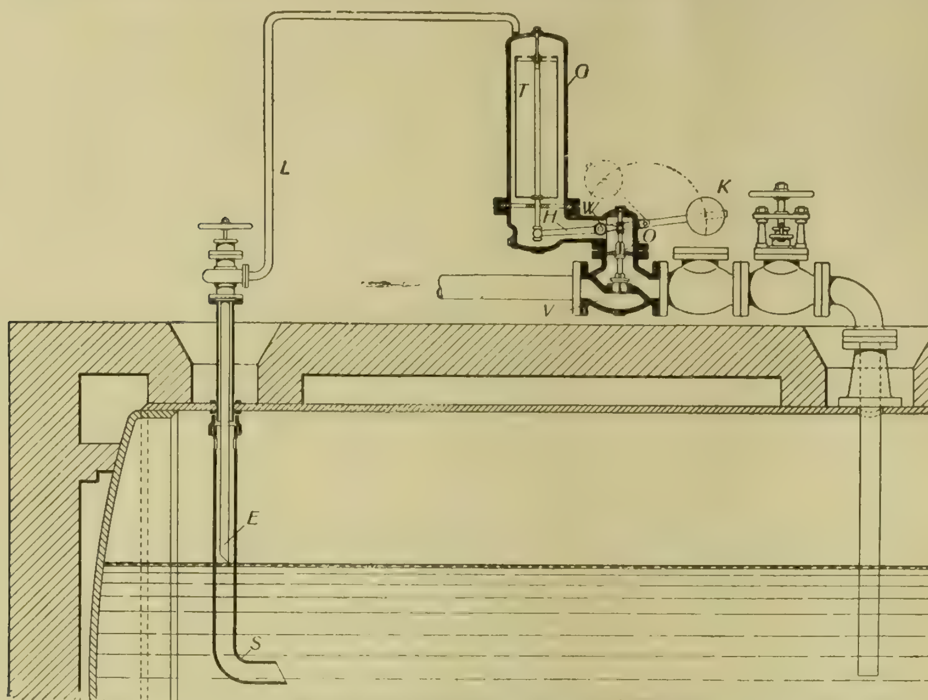


FIG. 24.—UNIVERSAL AUTO BOILER FEEDER, SHOWING FEED OPEN. ORIFICE OF TUBE E UNSEALED. MESSRS. KATER & ANKERSMIT, LONDON.

The connecting bar between the prongs, which is clearly shown in the illustration, is indented on the under side to allow it to be broken into required lengths (cutting pliers not being required), and the use of a single section on any width of belt up to 12in. This indentation also insures that in use over heavily crowned pulleys the bar may be broken without weakening the lacing, as each indentation separates a full staple which retains its own efficiency.

The pin consists of two specially formed steel wires having oval faces with lugs on their back, to fit in between the loops of the hinge and keep it from working out. In service the sections of the pin remain stationary in the loops of the lacing, and give the necessary flexibility to the joint by rocking on their oval faces.

Other manufactures shown by the firm were belt-lacing machines, and tools of various kinds; "Stephenson's" bar belt dressing, and Stone's easy car pusher, the latter being a special form of pinch bar, for use in moving cars, railway wagons, &c., along the metals by man power alone.

Messrs. Vickers, Ltd., of Vickers House, Broadway, Westminster, London, S.W., exhibited several variable-speed and one constant-speed motors of their manufacture on the stand of Messrs. William Asquith, Ltd., of Halifax. These included motors of 10 h.p., 7½ h.p., and 5 h.p., the first-mentioned being of the type used in connection with the well known "Vickers" reversing gear, which is largely used in connection with planing machines, and other heavy reciprocating machine tools. The remaining motors and the whole of the control gear came from the Birmingham works (The Electric and Ordnance Accessories Company, Ltd.). These motors were of the usual standard industrial type.

The control gear for the constant-speed motor consisted of the usual faceplate type of starter, mounted in conjunction with "Vickers" ironclad combined switch and fuse.

The control gear for the variable speed motors was of a quite special type, which is applicable to all industrial motors, and especially for those cases where the service is rendered particularly severe by frequent stopping and starting, and where the apparatus has to be operated by men who are not skilled in the use of electrical appliances. In this control pillar, the contacts are of the barrel type, having arc shields and magnetic blowout, and a double-pole circuit breaker is incorporated in the design. When speed variation is required, the shunt regulator is operated by the main starting handle, and when reversing is required, an additional barrel with a separate handle is provided. All these devices are either mechanically or electrically interlocked in such a way as to make the pillar absolutely foolproof.

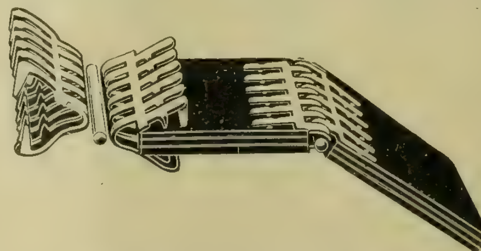
On another stand Messrs. Vickers, Ltd., exhibited vanadium high-power drills and one-lock adjustable reamers. These were shown at work; the drills in an "Asquith" vertical machine, and the reamers in a "Roberts" vertical boring mill, both of these machines being driven by motors of Messrs. Vickers' manufacture.

The *whole* of the drill, including the taper shank, is formed from one twisted flat bar, and this twist of the shank, it is claimed, gives great holding power with a total absence of a tendency to "jam." The tang also is relieved of all strain and consequently cannot break, while the shank accurately centres the drill and keeps it in perfect alignment. They are made in all sizes from ⅜in. to 3in. in diameter (rising by $\frac{1}{64}$in.), and a large assortment were on view on the stand.

An ingenious and very effective socket for securing a thorough distribution of the load on the shank was also shown. This result is obtained by means of an internal stud which engages with the convolutions of the drill shank, and in consequence the drill tends to screw up into the socket. The shank is thus brought into perfect contact with the surface of the socket, and a rigid drive is ensured.

The reamer was shown taking both roughing and finishing cuts. Expansion is obtained by the longitudinal movement of a cone on which the blades are bedded, the adjustment being very simple. The operator slacks out a locking nut slightly, and then places an adjusting key in pin holes provided in the cone bolt. Turning this in a clockwise direction expansion is obtained. Each small division on the face of the cone bolt corresponds to $\frac{1}{4000}$in. variation in diameter, while in the metric dimensions each division is equal to 1/100 mm.

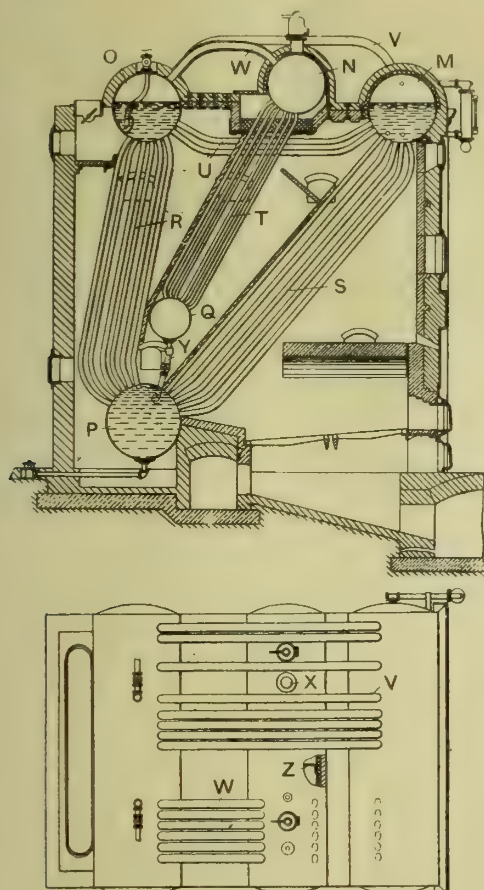
In repetition work it is generally essential that a number of holes should be parallel and strictly correct in diameter.


FIG. 25.—"ALLIGATOR" STEEL BELT LACING. MESSRS. J. B. STONE & CO., LONDON.

The Vickers adjustable reamer provides for this because by the removal of the box spanner and adjusting key it is not possible for the operator to tamper with the adjustment of the tool. The range of expansion varies from ·035in. with a 1in. reamer up to ·154in. with a 6in. tool.

COMBINED SUPERHEATER AND WATER-TUBE BOILER.

A combined arrangement of superheater and water-tube boiler, the invention of Mr. John E. Bell, of Barberton, Summit County, Ohio, U.S.A., is shown in the accompanying views, in which M, N, and O indicate the top drums of the



Combined Superheater and Water-tube Boiler.

boiler, P the bottom drum, and Q the lower drum of the superheater. The drums M and O are connected with the drum P by the banks of water tubes R and S, while the drum N is connected with the lower drum Q by the superheater tubes T. The water spaces of the steam and water drums M and O are directly connected by water circulators U, and steam tubes V lead from the steam space of the drum M to that of the drum O. Steam pipes W lead from drum O back to the intermediate drum N, which is the upper drum of the superheater forming the middle pass. The steam, by its passage through the pipes V, drum O, pipes W, and drum N, loses its moisture to a large degree, and passes down through some of the superheater tubes T to the drum Q and thence back through others to the steam outlet X from drum N. The drum N has an intermediate transverse partition Z, tubes W entering it on one side of this partition and the steam outlet X being on the other side. The tubes V are at one side, as shown, so as not to interfere with the return steam tubes W. The water circulators U extend between the superheater tubes and may be arranged in groups or singly. The drum Q is connected with the mud drum P by pipes Y. In this way the superheater may be flooded, and may be used as part of the water-heating surface of the boiler.

Pit Cage Accident. — An alarming accident, happily unattended by loss of life, occurred at the St. Hilda Colliery, South Shields, on the 7th inst. Coal drawing was in operation, and two cages were about midway in the shaft, when a rope broke, and a laden cage crashed to the bottom.

Obituary. — We regret to announce the death of Mr. Dugald Drummond, chief mechanical engineer of the London and South-western Railway, and formerly locomotive superintendent of the Caledonian and North British Railways, which took place at his residence in London on Thursday of last week.

DEVELOPMENT IN AUXILIARY UNITS BETWEEN EXHAUST PIPE AND BOILER.*

By William Weir.

(Concluded from page 576.)

Feed-water Heating.

The development in marine feed-water heating in the last 25 years has merely consisted in the adaptation of design to suit the conditions imposed by varying requirements for different classes of vessels. As regards types of feed heater, there are only two, direct contact and surface. There are also two locations, the first being on the suction side and the second on the discharge side of the feed pump. The heating steam may be obtained from two sources, auxiliary exhaust and receiver steam, and on these six variants many different arrangements have been devised.

Broadly speaking, direct-contact heaters should be, and generally are, of universal adoption, on account of their simplicity and of the outstanding advantage of their ability to eliminate the corrosive gases from the feed-water. Their universal adoption is, however, controlled in lighter draught vessels and in warships by the necessity of placing them high up in the ship, and also to a slight extent by a disinclination to mix auxiliary exhausts direct with the main feed on account of the suspected boiler troubles due to oil. In very large ships where the exhaust of single auxiliaries, such as electric-light engines of considerable power, do contain oil in a considerable amount, this argument is tenable, but when it is considered that almost 5,000 vessels are now running satisfactorily with direct-contact heaters, many of them 25 years old, and in addition that there are probably more cases of trouble with oil in boilers on vessels without direct-contact heaters than with them, some other explanation must be looked for in connection with this difficulty.

As regards location, direct-contact heaters are necessarily always on the suction side of the feed pumps, while surface heaters are most frequently arranged on the discharge side,

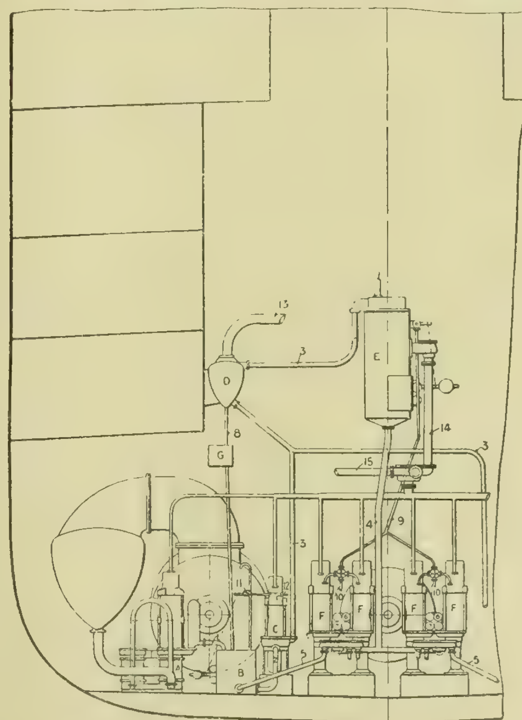


Fig. 11 - Arrangement of Feed-water System.

1. Air pump discharge to hot-well tank. 2. Hot-well pump suction. 3. Hot-well pump discharge through surface feed heater to the direct-contact heater. 4. Feed-pump suction from direct-contact heater. 5. Feed-pump suction from hot-well tank. 6. Feed-pump discharge to boilers through main feed pipe. 7. Feed-pump discharge to boilers through auxiliary feed pipe. 8. Condensed steam drain from surface heater. 9. Regulated steam to feed pumps. 10. Direct steam to feed pumps. 11. Regulated steam to hot-well pump. 12. Direct steam to hot-well pump. 13. Generator sets exhaust to surface feed heater. 14. Auxiliary exhaust to direct-contact heater. 15. Auxiliary exhaust to auxiliary condenser

although not necessarily so. A discharge surface feed-water heater offers the only method of obtaining very high degrees of feed heating over say 230° Fah.

As regards the source of heating steam, the essential principle is to use, in the first place, all the auxiliary exhausts and then supplement from the low-pressure receiver. In

* Paper read before the Institution of Engineers and Shipbuilders in Scotland, October 22nd, 1912.

earlier days the proportion of auxiliary exhausts to the main feed quantity was low, now it has greatly increased. In ordinary cargo steamers these exhausts will, on the average, heat the feed-water through a range of about 70° Fah., and in some passenger steamers through a range of 90° Fah., while in turbine vessels, and especially combination vessels, the range is rendered much higher on account of the increased efficiency of the main installation as compared with reciprocating installations, and also by the additional steam required for independent air and very large circulating pumps, together with the provision of oil-lubricating and water-service pumps. These represent increases on the auxiliary exhaust supply, while for the same power the main feed-water itself is decreased.

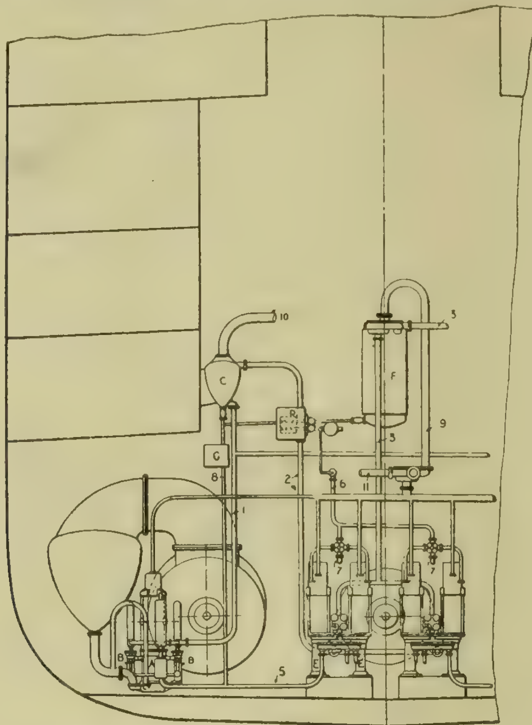
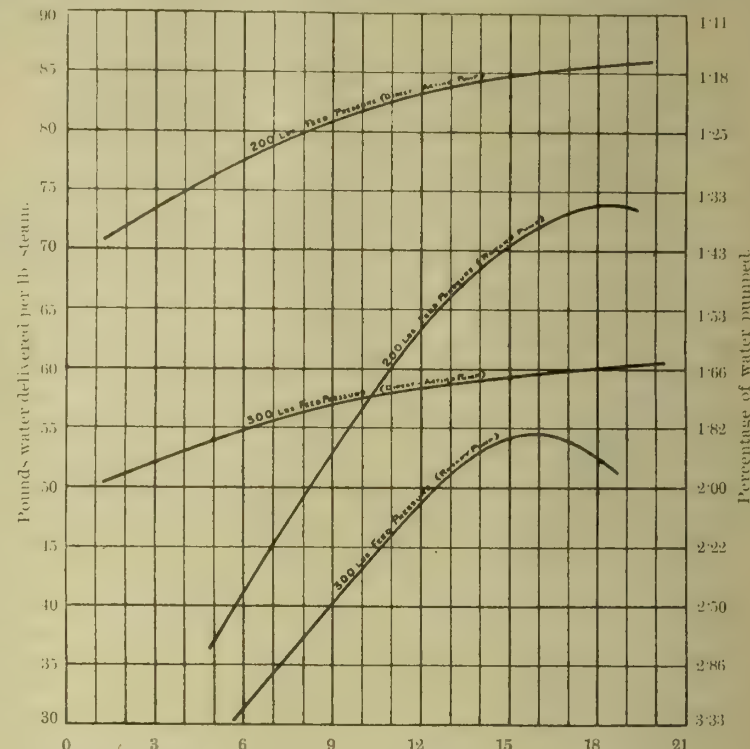


Fig. 15.—Arrangement of Feed-water System.
1. Hot-well pump discharge to low-pressure heater. 2. Feed-pump suction from float tank. 3. Feed-pump discharge to "Multiflow" heater and boiler. 4. Feed-pump discharge in boiler direct. 5. Feed-pump suction from hot-well. 6. Regulated steam to feed pumps. 7. Direct steam to feed pumps. 8. Drain from feed heaters to hot-well through gravitation filter G. 9. Auxiliary exhaust to multiflow heater. 10. Auxiliary exhaust from electric engines to low-pressure heater. 11. Auxiliary exhausts to auxiliary condenser.

Fig. 14 shows a diagrammatic representation of the feed heating installations and general treatment of the feed-water on some of the highest-powered vessels afloat. It is specially applicable to vessels fitted with large electric-light installations where the generators are driven by reciprocating engines of which the exhaust steam contains a certain proportion of oil, and where it is not generally advisable to lead the exhausts from such engines into the same exhaust pipe as the other auxiliaries on account of the fluctuations in pressure. In this installation the "Dual" air pumps A deliver to the hot-well tank B, from which the independent hot-well pump C draws the water and delivers through the low-pressure surface feed heater D to the direct-contact heater E. The main feed pumps F then draw from the direct-contact heater and deliver to the boilers through the main or auxiliary pipes. The supply of heating steam to the surface heater D is the exhaust from the high-speed reciprocating engines driving the electric generators, and the condensed drain water from this heater passes through the gravitation filter G to the hot-well tank B. The heating steam to the direct-contact heater E will be all the auxiliary exhaust steam, with the exception of the exhaust from the generator sets already mentioned.



For direct-acting pump, double strokes per minute.
For rotary pump, similar variations in capacity at constant speed.

Fig. 17.—Diagram of Steam Consumption of Feed Pumps.

Fig. 15 shows an arrangement for large vessels, where it is desired to separately filter the whole of the condensed auxiliary-exhaust steam before mixing it with the main feed supply. In addition, this arrangement enables the maximum temperature of feed to be obtained in cases where there is a very large ratio of auxiliary exhaust to the main feed supply. This arrangement is also interesting as showing the application of hot-well pumps attached to the main air pump for pumping the feed water through the first-stage feed-heater. The installation consists of two or more pairs of Weir feed pumps, "Dual" air pumps, with attached hot-well pumps (independent hot-well pumps may alternatively be fitted), low-pressure surface feed-water heater C and "Multiflow" high-pressure feed-water heater. The "Dual" air pumps A discharge into self-contained hot-well, from which the hot-well pumps B draw and deliver through the low-pressure heater to a float tank D. The main feed pumps E draw from the float tank D, in which is contained their control gear, and deliver to the boilers through the "Multiflow" feed-water heater F, or through the auxiliary feed pipe.

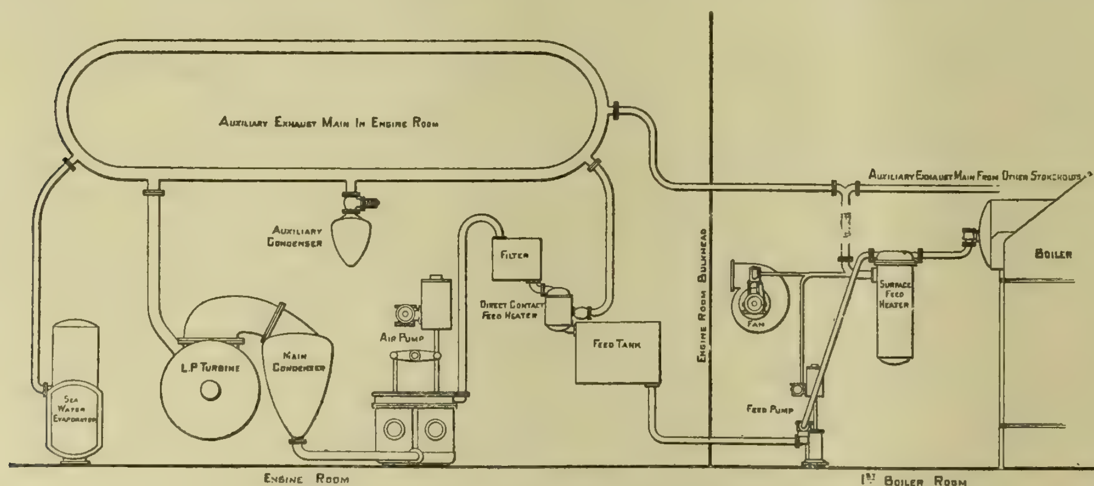


Fig. 16. Feed-heating Arrangement for Warships.

In this arrangement the electric engine exhausts are led

to the first or low-pressure heater C through the pipe 10; the remainder of the exhausts are led to the high-pressure feed-heater, and a pressure up to 15lbs. may be maintained in the auxiliary exhaust pipes to enable the feed-water through a much greater range.

Fig. 16 shows diagrammatically the arrangement used on some recent large war vessels in which feed heating is done in two stages. In a small direct-contact heater of light weight and extreme simplicity fitted to the feed tank, the feed is raised in temperature by contact with auxiliary-exhaust

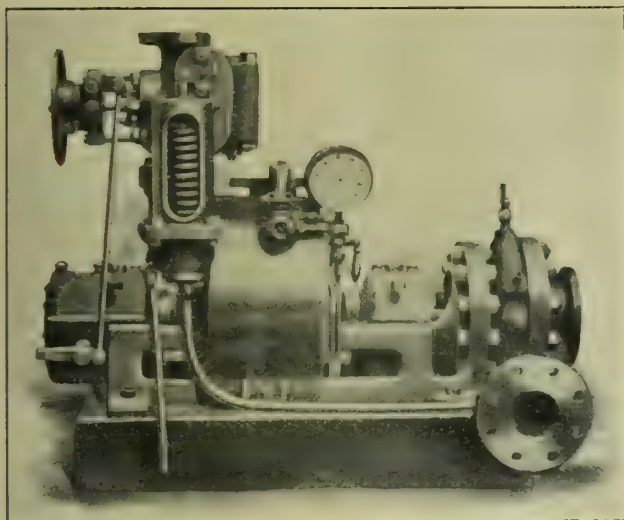


Fig. 18.—Weir "Rotofeed" Pump.

steam to about 140° Fah. It is then heated to over 200° Fah., also by auxiliary-exhaust steam in small surface feed heaters placed in the stokeholds and fitted on the feed-discharge pipes. The preliminary heating enables a great reduction to be made in the size and weight of the high-pressure heaters.

Independent Feed Pumps.

The detailed history of the development of the independent feed pump would be largely a recital of endless experiment with and investigation of mechanical details. The

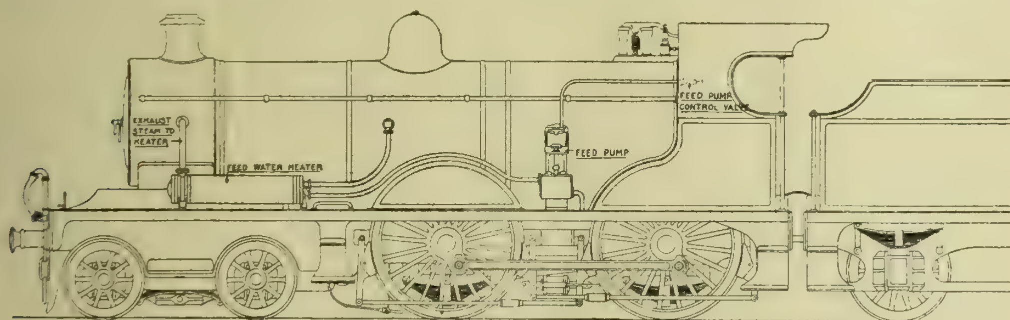


Fig. 19.—Weir System of Locomotive Feed Heating and Boiler Feeding applied to Main Line Passenger Locomotive.

difficulty of regulating a crank-driven machine, together with the great and variable stresses, rendered this type quite inapplicable for high-pressure boiler feeding. Stroke variation and high steam consumption, together with the multiplication of parts, similarly handicaps the duplex type. Accordingly the single direct-acting pump has become the standard, and when arranged in conjunction with feed heater or tank float-control, this type has become universal in its use.

The general and even the detail design of the pump ends, which at one time varied mainly in their degrees of inefficiency, has now become standardised by almost all makers adopting the same design, and the remaining difference of the many types, apart from workmanship and material, lies in the steam-distribution valves. On such a subject as the history of these, a separate paper might be written.

A point of interest in direct-acting feed pumps concerns itself with their steam consumption at varying speeds and boiler pressures, and as such does not appear to have been hitherto published, Fig. 17 shows a set of curves which represent neither the best nor the worst performances, but which can be taken as representative of actual every-day practice.

During recent years a certain amount of experimental work has been carried out with rotary feed pumps of the centrifugal type, and on the Continent a number of these have been installed in electric power stations. The application of this type of pump to marine use is of great interest, and it is rather unfortunate that the bulk of the experience obtained on shore has been with electrically-driven centrifugal pumps. If it were possible, or even prudent, to drive marine feed pumps by electric motors, then it is believed their adoption would be rapid on account of the properties of the electric motor as regards non-variation in speed, and in this connection it is more than questionable whether electrically-driven feed pumps constitute good practice even for electric power stations. On board ship the feed pumps should be driven in every case by the same source of power that actuates the main machinery, and this at once involves the adoption of either a rotary steam engine or a steam turbine in conjunction with the centrifugal pump. The successful combination of centrifugal pump wheels with a small steam turbine is a problem which, while to a certain extent solved, is one requiring the utmost care and knowledge of design and materials, while the application of the combination to meet the conditions of varying load on board ship will require considerable and extended experience. Fig. 18 shows a "Rotofeed" pump designed for 300lbs. boiler pressure. A considerable number of these machines are now running and in the course of manufacture, with a view to developing a suitable machine for the varied conditions of marine service. For land work they are thoroughly satisfactory, particularly for large units, but the marine application requires considerable caution, and it appears difficult at present to regard them as suitable for universal use in ordinary vessels. Their initial adoption will probably be for installations where the outstanding advantage of this type of pump is prominent, *i.e.*, the saving in weight and space on board war vessels.

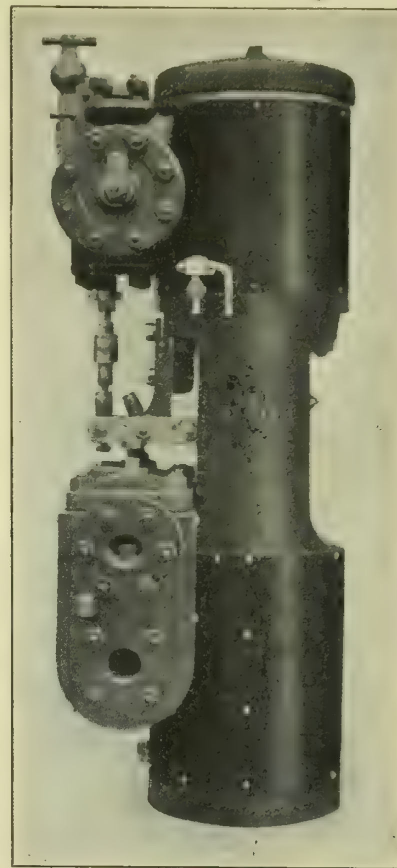


Fig. 20. Weir Locomotive Feed Pump.

On the steam-consumption diagram for direct-acting pumps there is also shown the performance of the turbine-driven type, and, as will be seen, this type is to a fair extent less economical. In the future this feature may be improved, while as a counterbalancing advantage for certain conditions the weight comparison is given in Table V., which shows the relative weights of direct-acting pumps for different

classes of vessels, and discloses a very large possible reduction by the rotary pump.

TABLE V.—*Comparative Weights of Independent Feed Pumps.*

Class of Vessel.	Feed pipe pressure, lbs. per square inch.	Weight of pump per H.P. of main engines.
Cargo vessel	210	·74
Mail steamer	210	·72
Channel steamer	210	·665
Battle-ship	285	·64
Destroyer	285	·43
Weir "Rotofeed" pump	285	·14

In concluding this note on feed pumps, while it is hardly directly connected with the subject of the paper, it may be of interest to show on Figs. 19 and 20 the latest development of the Weir pump for locomotive feeding, wherein it is associated with a special design of exhaust-steam feed-water heater. The adoption of this apparatus secures a considerable degree of coal economy, and the advantages of steady boiler feeding for this purpose, as compared with the non-flexible injector, are obvious.

FEED MAKE-UP APPARATUS.

Since 1885, when the first commercial feed make-up evaporator was constructed by Mr. James Weir, practically the development has been one of detail, and such detail has to a considerable extent been associated with the innumerable methods of arranging the heating surface for its easy and satisfactory withdrawal for cleaning purposes. The original evaporators used receiver steam in the coils, and the vapour was discharged to the feed heater. The universal practice now is to utilise boiler steam in the coils, except in H.M. Navy, where the auxiliary exhausts are used. In the last 12 months some rather revolutionary developments in the

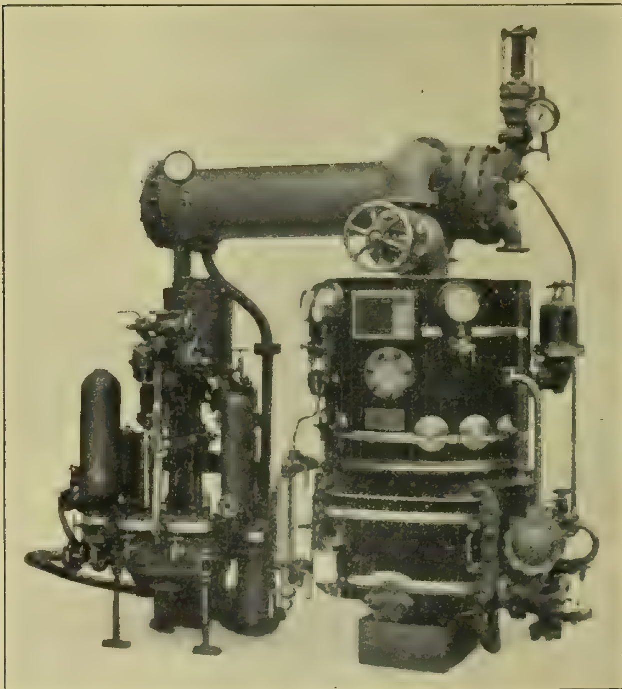


FIG. 21.—WEIR EVAPORATING AND DISTILLING PLANT (1912).

design of evaporators have been made, and Fig. 21 shows a representative installation for warship use, while a copy of the trial results is given on Table VI. along with similar data from the practice of 1895.

CIRCULATING PUMPS.

With regard to this auxiliary, the development has not been in type but rather in the field of design. The early circulating pumps were, of course, engine driven, and of the double-acting piston type; but, as dimensions and speeds increased, the independent pump became necessary. The low head and large quantity of water necessarily involved the adoption of the centrifugal pump, and it appears difficult to foresee any further development of type. The advent of the turbine for auxiliary driving may, however, influence the future of the circulating pump to a considerable extent, as it is certainly the most adaptable auxiliary for the new type of prime mover. Comparatively few examples of these

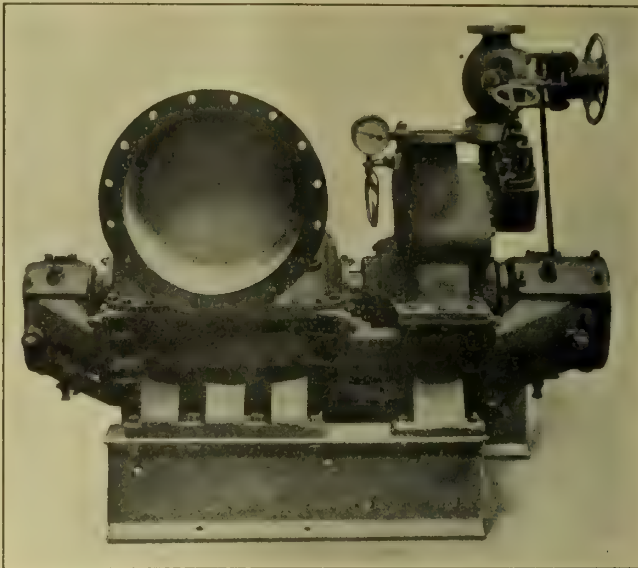


FIG. 22. WEIR TURBINE-DRIVEN CIRCULATING PUMP.

pumps for marine use are in existence, and Fig. 22 shows the first unit of this type supplied for torpedo-boat use in this country. In this design the special features embodied are efficiency at low powers and simplicity. It may be of interest to state that the reduction of weight is most marked, together with the general suitability of the pump, in installations of very large power.

TABLE VI.—*Comparison of Evaporating and Distilling Machinery. Weights and Performances.*

Data.	Installation for Small Cruiser (1895).	Installation for Small Cruiser (1912).
Evaporator heating surface	85·5 sq. ft.	37·3 sq. ft.
Distiller cooling surface	46 sq. ft.	85 sq. ft.
Weight of evaporator	38 cwts.	14¼ cwts.
Weight of distiller	2½ cwts.	5¼ cwts.
Weight of all pumps and pipes	14¾ cwts.	12½ cwts.
Weight of water in installation	12 cwts.	4 cwts.
	Trial performance.	
Steam pressure in coils	85lbs.	135lbs.
Steam pressure in shell	19lbs.	3lbs.
Production in gallons per hour	244	390
Drain from coils in gallons per hour	299	460
Ratio of drain to gained water	1·22	1·18
Circulating inlet temperature	85°	80°
Circulating outlet temperature	No record.	132°
Condensed water temperature	106°	140°
Brine discharge in gallons per hour	122	200
Ratio of brine to gained water	·5	·51
Nitrate test	Fresh	Fresh
Weight of plant per ton of fresh water	288lbs.	98lbs.

Hardening and Tempering of Steel.—Reference is made in a pamphlet recently issued by the United States Bureau of Mines to the necessity of adopting the latest methods in the hardening and tempering of steel, if waste is to be avoided. An instance is recorded in which a manufacturer, at present making about 300,000 steel blades a day, has reduced his costs more than one-half through the adoption of up-to-date methods. About three tons of cold-rolled steel per week are now used. The blades were formerly hardened by using 65 machines which utilised gas and blast for the heating process, ran day and night, and required 15 men for their control. On the advice of an expert chemical engineer six electrically-heated furnaces have been installed which, in an eight-hour day, give double the old capacity and require the services of only two operators. For the tempering process, the blades, 70lbs. at a time, are dipped into an electrically-heated salt bath, and are held for a definite period at a temperature precisely controlled by pyrometers.

THE GENERATION AND ELECTRICAL TRANSMISSION OF POWER FOR MARINE TRANSPORTATION.*

BY WILLIAM P. DURTNALL.

Mechanical power was first applied to propulsion in 1543, by Plasco de Garay, a Spanish sea captain, who is said to have succeeded in giving motion to paddle wheels by the use of steam. Various attempts have been made to use the propulsive force of a jet of water, and in 1661 a patent was granted to Thomas Toogood and James Hayes for a method of propelling ships by forcing out water through the bottom of a vessel. Early experiments and patents in propulsion by mechanical power were those of Robert Hook in 1681, with a feathering paddle wheel, and of Joseph Bramah, an engine maker of Piccadilly, in 1785, with his rotary steam engine, and worm gear driven stern paddle wheel, or screw type propellers.

Screw propulsion was, however, practically introduced about 1835, by Francis P. Smith, a farmer, of Hendon, Middlesex. On May 31st, 1836, a model boat fitted with a wooden screw was exhibited in operation on what is now the Welsh Harp pond at Hendon, and was inspected by Sir John Barrow, Secretary to the Admiralty. The results were deemed so satisfactory that in the autumn of the same year a boat was built of six tons burden and about 6 h.p., with a wooden screw consisting of two turns. On November 1st, 1836, she was exhibited in operation on the Paddington Canal, and continued to ply there and on the Thames until September, 1837. In February of that year, an accident showed the advantage of diminishing the length of the screw, about half the length of the propeller being broken away, whereupon the boat immediately quickened her speed, and a higher thrust was produced for the same shaft horse-power. The sea-going capabilities of the boat were then demonstrated, but before the Admiralty would give a decision they insisted that the screw propeller should be tried on a vessel of at least 200 tons. The "Archimedes," of 237 tons, was therefore built at a cost of £10,500, and was fitted with 80 h.p. engines. It was designed for a speed of 4 or 5 knots, which on trials was about doubled.

The Admiralty then decided to adopt the screw propeller in the Navy. Some further experiments were carried out by Mr. Brunel, at Bristol, following which the "Great Britain," originally built for paddle wheels, was fitted with a screw propeller, and was the first screw-driven boat to cross the Atlantic. A number of professional men at that time did not believe that a steamship, owing to having to carry machinery and coal, instead of using the wind for propulsion, could cross the Atlantic, which goes to show how theory may often be upset by practice, and the theory of some modern engineers that electrically-driven sea-going vessels are impracticable may meet with a similar reverse in the near future.

The engines of the "Great Britain" ran at 18 revs. per minute, while the propeller shaft was geared up to 54 revs. per minute, the propeller having six blades, and the steam pressure being 25lbs. by gauge. This boat ran fairly successfully under steam from 1843 to 1874, when she was converted into a fully-rigged sailing ship. The gearing between the engine and the propeller was a source of trouble and decreased efficiency, until Smith joined forces with Captain Ericsson, a capable engineer and navigator, who increased the speed of the engine, and direct-coupled it to the propeller. Every credit must be given to those early workers in marine transport, who experienced great opposition from many quarters and not only had not the advantage of modern machinery, but had to educate navigators, shipbuilders, and owners who were not engineers, were opposed to new methods of propulsion, and had very little desire or ability to master the higher branches of either navigation or mechanical sea transport.

Ericsson later went to America, and in 1853 constructed a craft in which one of the boldest attempts was made to find a substitute for steam. This was the "Ericsson," which had two masts, and ordinary paddle wheels 32ft. diam., but no funnels, the machinery being operated on what was then known as the "caloric" principle, which rendered them unnecessary. She was 250ft. long, 40ft. broad, and 31ft. deep, with a gross tonnage of 1,920, and a speed of 12 knots for a consumption of 6 tons of coal per day. She was practically a hot-air propelled ship, and Mr. Ericsson was then probably very near to the discovery of the internal-combustion engine. To him is also due the invention of the "Monitor" type of warship, which rendered such enormous service in the American war, this ship being the one which encountered and disabled the "Merrimac" and saved the American Navy of that day from annihilation. To him also we owe the idea of protecting propellers from hostile shot, and many other ingenious inventions, which entitle him to rank as one of the greatest inventors that the world has ever known.

An interesting attempt to solve the problem of propulsion was that made in connection with H.M.S. "Waterwitch," an iron-plated gun-boat 162ft. long, 32ft. beam, and 9ft. 9in. draught, with a displacement of 1,062 tons. She was propelled either head or astern by means of two water jets placed close to the hull, and taking advantage of the hull wake effect. The jets were produced by a steam-driven 3-cylinder engine, running with the crank shaft vertical, coupled to a kind of rotary pump, which drew water from the underside of the vessel and delivered a jet at each side. With an expenditure of 750 i.h.p. the speed obtained was 9 knots, this performance being considered very inefficient, as compared with a screw propeller, and the scheme therefore dropped. If an effort were made to reintroduce the system to-day, using electric motor-driven turbine pumps, and many more jets, and arranging for the water inlets to be facing the direction in which the boat is proceeding, something might come of it, for jet propulsion possesses the advantage that the propelling apparatus is not only well below water level, but inside the boat and therefore not easily damaged by projectiles as are other forms of mechanical propellers.

We now come to the "Great Eastern," which was propelled both by paddle wheels and a screw propeller, had five funnels, was 680ft. long, 82ft. beam, and had a loaded draught of 30ft. The displacement was 27,000 tons, while she had four decks and six masts, with a sail area of 6,200 sq. ft. Ample attention was given to the provision of bulkheads, of which 12 were transverse and two longitudinal, and the spaces were used as coal bunkers, an idea originated by the genius of Brunel, and copied by the designers of the "Lusitania," the "Mauretania," and other modern vessels. The paddle wheels of the "Great Eastern" were 56ft. diam., with float boards 13ft. long and 3ft. wide. The screw propeller had four blades, a diameter of 24ft., and a pitch of 37ft. Five boiler-rooms were provided to supply steam at a pressure of 25lbs. per square inch by gauge, the total indicated horse-power being about 8,000. She was, however, a commercial failure, for steam engineering had not then reached the efficiency necessary to ensure success. Signs are not wanting now that the size of ships has again reached a point where, unless a further increase in the thermo-dynamic efficiency is attained, great financial losses will be experienced.

Since the days when Ericsson coupled his engine direct to the screw propeller countless efforts have been made to increase the efficiency of ship propulsion. For instance, the steam engine, instead of working by single expansion, was compounded, which increased the efficiency and reduced the fuel consumption; then followed the triple-expansion engine, which gave further increase in efficiency; progress also took place in the design of hull, and considerable research work was done with regard to propellers working under various conditions. Great improvements were introduced in the operation and construction of steam boilers, and an attempt was made to introduce the water-tube in place of the fire-tube marine boiler, with a view to reducing the dead-weight, thus again increasing the over-all thermal efficiency of the vessel measured by the number of heat units used per thousand ton-miles at a given speed.

One of the most efficient trials of a cylindrical fire-tube boiler was conducted on the "Saxonia," kindly lent for the purpose by the Cunard Steamship Company between October, 1903, and May, 1904. She is a vessel of 14,281 tons, 580ft. long, 64·2ft. beam, and 38·4ft. deep, driven by twin screws and quadruple-expansion steam engines, and was at the time considered a very efficient ship. The boilers showed a thermal efficiency of 82·3 per cent. with a feed-water temperature of

* Paper read before the Society of Engineers, November 4th, 1912.

178° Fah., and an evaporation of 11·3lbs. of water per pound of coal burnt, over a run of 13 hours, during which period only six of the 27 furnaces were cleaned. The boiler-room equipment of the "Saxonia" weighed about 1,000 tons, and produced an output of 132,600lbs. of steam per hour, or 132·6lbs. per ton weight of the boiler installation. The total steam consumption per indicated horse-power hour was only 13·26lbs., showing that the quadruple-expansion type of engine is very efficient from a thermal, if not from a mechanical, point of view. Boiler efficiency does not seem to have made much, if any, improvement since that date, but great progress has been made in other directions.

Reciprocating steam engines, although greatly improved and brought up to a fine state of efficiency as such, have grave disadvantages, the greatest perhaps in the case of passenger ships being the unavoidable vibration, as it is a natural law that a revolving body which is not exactly balanced always runs unequally, and transmits a tremor to anything with which it may be in contact. Large power engines of this type as required in modern high-speed vessels of heavy displacement, stand so high in the ship that their cylinders are well above water level; this being a special disadvantage in warships, and is no doubt one of the reasons why the steam turbine has replaced the efficient reciprocating steam engine in the British Navy.

The measure of the commercial efficiency of a ship in the mercantile marine is roughly the ratio of the dead-weight of freight carried at a given speed to the amount of fuel consumed in the process, the effective horse-power produced on a ship is estimated from pounds produced in thrust × by vessel speed in feet per minute ÷ 33,000 = E.H.P. It may be well to mention here that the mechanical equivalent of heat is represented by 778 ft.-lbs. of work done, this quantity being called a British Thermal Unit. One pound of, say, Welsh coal contains at least 15,000 units of heat, and if this 1lb. of coal is burnt in one hour it is equivalent to 11,580,000 ft.-lbs., or nearly 6 h.p. An ordinary tramp steamer consumes on an average approximately 1½lbs. of coal per indicated horsepower hour, from which it is clear that enormous thermal losses take place daily in thousands of ships. These losses and their causes may be roughly stated as follows:—

Fuel heat distribution.	Per cent.
Heat in gases passing through funnel (some part of this is used for maintaining boiler draught)	20
Surface radiation from boiler	10
Heat absorbed by condenser and auxiliaries	56
Steam friction in cylinder	2
Steam condensation in cylinder	2
Mechanical friction in engine and propeller shaft	3
Propeller and other losses	3
	96
Thermal propulsive efficiency, *i.e.*, efficiency of propulsion expressed as a percentage of fuel heat	4
	100

That is, the equivalent of 100 h.p. in fuel units at the furnaces produces only 4 h.p. of actual propulsive effect, or the "thermal propulsive efficiency" is only 4 per cent. If a high thermal propulsive efficiency for a given speed and displacement were insisted upon as a standard of excellence a vast decrease in the cost of the sea transportation would be effected, to the benefit of both the shipping trade and the public. It is well known that a screw propeller to produce a maximum thrust must run below a certain critical speed, beyond which slip and blade friction losses occur, and cavitation sets in. The results of numerous trials show that the pressure per square inch of projected area is approximately 1lb. for every 1,000ft. per minute circumferential velocity of the blade tips. At full speed and power the pressures seem to be for slow cargo vessels from 5lbs. to 6lbs. per square inch, for ocean-going mail steamers from 6lbs. to 7lbs., for cross-channel boats 7·5lbs. to 8·5lbs., for cruisers and battle-ships 8lbs. to 10·5lbs., and in some torpedo craft 9lbs. to 11lbs. About 9lbs. per square inch, or rather less, is the lower limit for turbine screws; from 10lbs. to 11lbs. for fast speed vessels, but pressures greater than about 11lbs. per square inch seem to give low thrust efficiency. The pressures referred to are estimated mean pressures, as there exists no method of accurately determining the local intensity per square inch, though it may be assumed in some cases.

Propeller efficiency presents a complicated problem depending on the form and speed of the boat. Small diameter high revolution screw propellers have been found to give much less thrust when the vessel is travelling against a head wind or tide, and such propellers are run close to the speed at which cavitation sets in, so that in case of real necessity for a spurt at high revolution speed to meet certain conditions when entering harbours, &c., there is a very small margin for increase of speed before cavitation sets in. Low speed propellers with their larger blade surface have a greater holding power under the above conditions, with the material advantage of allowing a reasonable increase in revolution speed to meet certain requirements at sea, which are not possible with the high speed type of propeller.

There is now a noticeable tendency to increase the diameter and reduce the revolutions of the propeller, while the use of twin screws is being advocated in place of triple or quadruple screws for heavy, high-speed vessels. The revolution speed is of great importance in connection with the means of driving the propellers, the fuel consumption and consequently the "thermal propulsive efficiency" of the ship at a given speed.

Until a suitable type of internal-combustion engine appears, steam will continue to be used for heavy marine propulsion; its economical generation is therefore of the very highest importance. A gas-fired steam generator shown at the recent Engineering Exhibition is stated to have a thermal efficiency as high as 90 to 93 per cent., and in the author's opinion the crude and old-fashioned methods of generating steam for prime movers in furnaces are doomed and will be superseded by this new and more efficient method.

The experience of sea-going engineers shows that the motive power for driving the propeller should conform to the following conditions: (1) The driving power must be simply and quickly reversible. (2) It must be capable of being started and stopped quickly. (3) It must be capable of being promptly speeded up and down from dead slow to full speed, or even in case of emergency be capable of increasing the revolution speed above normal for short periods of time. (4) It must be capable of being kept running at any desired set speed and of running economically at that speed for very long periods. The "dead-slow" speed should if possible be slower than one-fourth of the normal full-speed revolutions, and in very fast vessels one-eighth or less. (5) It must be capable of working well and reliably in smooth or rough water with the power varying from zero to sometimes more than the normal maximum for short periods, when the propeller experiences rapid changes in resistance to rotation. (6) It must meet the previous conditions without racing or showing more than, say, 5 to 8 per cent. deviation from the normal set speed, and in the case of heavy rolling, means should be provided to vary the power automatically from port to starboard propellers when operating two or more propellers. (7) All working parts must be readily accessible for overhauling and adjustment, and all wearing surfaces must be capable of being easily examined. (8) The driving machinery must be economical in fuel at all speeds, especially at the normal full speed at which it is generally run, and the machinery should have the least number of working parts.

Fractures in the tunnel and tail shafts sometimes occur in spite of careful inspection, and such an accident is very serious, especially on single screw vessels, and may even lead to the loss of the ship. A ship being practically a flexible girder, the longer the propeller shafts are the greater the strains set up in them, and this source of danger should be minimised by making the shafts as short as possible. This is done in some vessels, such as cargo boats, in which it is preferred to have the machinery at the stern to give by its weight sufficient propeller immersion when travelling light, but in passenger boats the boilers and machinery are generally placed forward, so that long tunnel shafts are unavoidable. Electrically-driven vessels have the undoubted advantage that the steam and power generating plant may be placed forward, whilst the propeller driving motors may be placed as far aft as the lines of the vessel will allow.

(*To be continued.*)

HEAVY OIL ENGINES.*

BY CAPT. H. RIALL SANKEY, R.E. (RETIRED), M.INST.C.E.

(*Concluded from page 596.*)

Cost of Running in Comparison with other Prime Movers.—It will be of interest to make a comparison of the fuel consumption of oil engines with that of other prime movers, and for this purpose Table IX. has been prepared, giving various typical cases, which shows that the Diesel engine is easily at the head.†

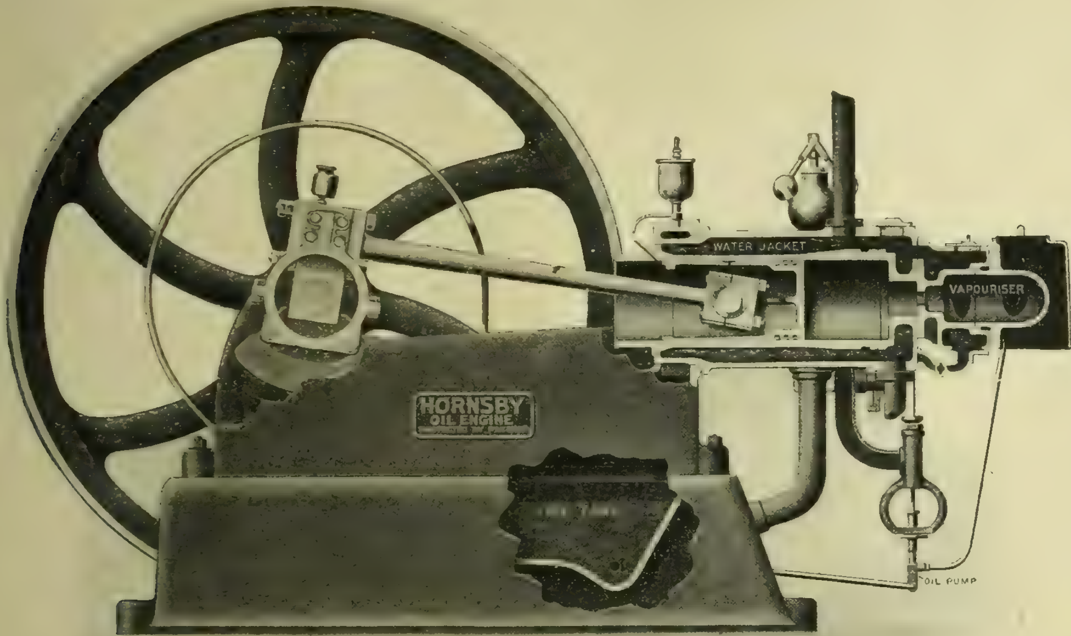


FIG. 31.—HORNSBY-ACKROYD OIL ENGINE.

In many industries a prime mover is required that has to give occasionally for short periods a considerably greater power than the average. In such cases the condensing steam engine has an advantage, because it can for short periods give as much as 50 per cent. above the rated power. In this connection, it may be pointed out that under similar circumstances the non-condensing engine can give 10 per cent. above the rated power and the Diesel engine can also give 10 per cent. above the rated power, but the gas engine, as usually rated in makers' price lists, can only do its rated power for short periods, and only 85 per cent. of that continuously. It is not only the cost of fuel that has to be taken into consideration when determining which is the best prime mover to use in any particular case, as the interest on capital, labour, depreciation, repairs, &c., must also be taken into account. To give some idea what this means, Table X. has been prepared. Assuming that the average load is 200 b.h.p., and that for short periods 300 b.h.p. is required, the rated powers of various prime movers would, therefore, be as follows:—

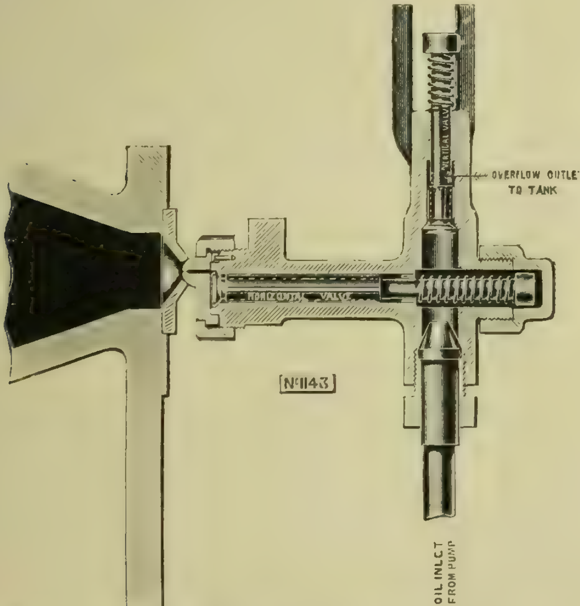


FIG. 32.—VAPORISER VALVE BOX, HORNSBY-ACKROYD OIL ENGINE.

Non-condensing steam engine	270 B.H.P.
Condensing steam engine	230 ,,
Overtype superheated condensing steam engine	230 ,,
Gas engine	300 ,,
Oil engine	300 ,,
Diesel engine	270 ,,

In Table X. the estimate for capital cost includes boilers, foundations, producers, building, &c. The cost of repairs, maintenance, and labour has been also estimated, and the plant is assumed to be run for 3,000 hours per year. The cost of fuel has been taken as follows:—

Oil	42s. per ton.
Coal for pressure producers	18s. ,,
Coal for suction producers	28s. ,,
Coal for steam boilers	18s. ,,

It will be seen that the annual cost of running the overtype superheated steam engine is £53 less than that of the Diesel engine when all conditions and items of expense are taken into consideration. The conditions assumed are not at all unusual for small plants, but obviously they may be so varied as to

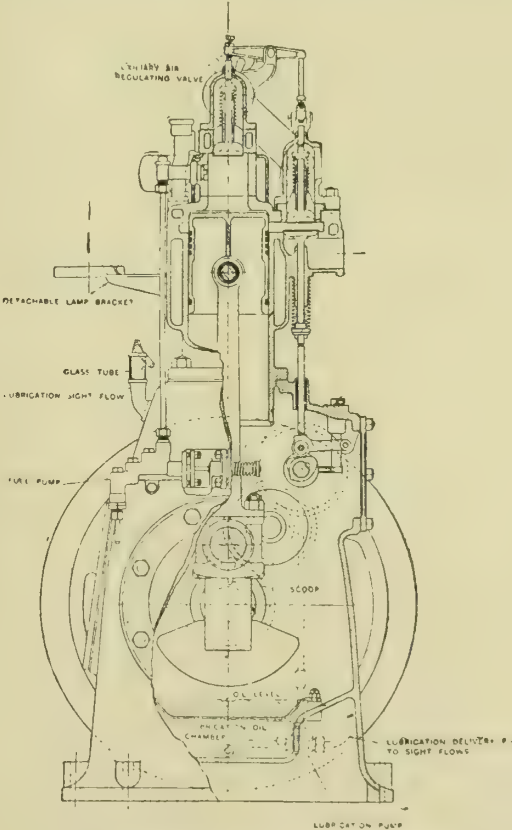


FIG. 33.—SECTION OF 10 H.P. CROSS OIL ENGINE.

* Howard lectures delivered before the Royal Society of Arts, April-May, 1912. Reproduced from the "Journal of the Royal Society of Arts."

† In most of the items two lines are given. The first refers to an engine whose rated load is 100 B.H.P., and the second to a larger engine capable of developing 150 B.H.P.

produce very different results, and each case must be considered on its own merits, but the above will give an idea how to proceed. Especially is it easy to make a correction should the price of fuel vary from that given above. Thus if the price of fuel oil is increased to 55s. a ton, the cost for fuel for Diesel engines would be $252 \times \frac{55}{42} = £330$, and hence the annual cost would be increased to £1,010.

Various Heavy Oil Engines.—The preceding remarks refer principally to Diesel engines. There are many other heavy oil engines on the market, both of the explosion and of the combustion type, and the following have been selected as being representative of the various types:—

The Hornsby-Ackroyd engine is one of the earliest of the explosion engines, and it is understood that some 40,000 of them have been made. Fig. 31 shows a section through the cylinder of one of these engines, and Fig. 32 gives an enlarged view of the vaporiser valve box. The relief valve is regulated by the governor; the oil pipe delivers a constant amount per stroke, and the amount not required to deal with the load flows back into the tank through the relief valve. The compression has to be adjusted to suit the oil in use; the most usual oil for these engines is Russian oil of a specific gravity of 0·823 to 0·825, but they also work satisfactorily with Texas oil of 0·933 sp. gr. The oil consumption is stated to be 0·674lb. of Texas oil. These engines are listed to about 370 b.h.p.

The Allen is an explosion engine with a hot-pot vaporiser; a blow lamp is used for heating the hot-pot for starting, or the engine may be started on petrol. The ignition is also ensured by a magneto, and these engines use paraffin oil of 0·82 sp. gr., and are built from 2½ b.h.p. at 800 revolutions to 75 b.h.p. at 500 revolutions.

The Cross engine, built by the Westinghouse Brake Company, is shown in Fig. 33. As will be seen, it has a divided combustion chamber, and there are two air inlets, one through the combustion chamber and a second through the valve pocket. As the piston nears the top of its stroke the supply through the valve pocket is cut off and a charge of air at 150lbs. pressure is trapped in this valve pocket. The fuel is injected at the top of the stroke in a fine spray by means of the special pump, a section of which is given in Fig. 34. There are two suction and two delivery valves driven by a cam and under the control of the governor. The fuel injected into the hot compression chamber ignites, no matter how small the load may be, and on the piston descending the air charge trapped in the valve pocket completes the combustion. The hot bulb

Table IX.

Description of Plant.	Calorific Value of Fuel, B.Th.U. per lb.	Total Fuel Required—lbs. per Hour at Various Proportions of Full Load. Quarter load. 25	Half load 50	Full load. 100 B.H.P.	10 per cent. Overload. 110	50 per cent. Overload. 150
Non-condensing steam plant	13,000	150	190	270	290	—
		200	240	320	340	410
Condensing steam plant	13,000	95	120	190	210	310
Overtype superheated condensing steam plant	13,000	55	75	130	150	230
Gas-engine pressure producer	13,000	37	59	93	—	—
		53	70	104	110	140
Gas-engine suction producer	14,000	34	53	85	—	—
		49	64	96	104	130
Oil engine	19,000	26	40	65	—	—
		33	46	72	78	97
Diesel engine	18,500	16	25	45	51	--
		19	27	45	50	69

Table X.

Description of Plant.	Capital at 5 per cent.	Fuel Weight.	Fuel Cost.	Stores Labour.	Maintenance, Repairs, Depreciation	Total Annual Cost.
	£	Tons.	£	£	£	£
Non-condensing steam plant	125	1,022	920	150	250	1,445
Condensing steam plant	120	607	546	150	240	1,056
Overtype superheated condensing steam plant	122	415	373	140	244	879
Gas-engine pressure producer	167	305	275	220	334	996
Gas-engine suction producer	147	282	395	170	294	1,006
Oil engine	150	193	405	200	300	1,055
Diesel engine	160	120	252	200	320	932

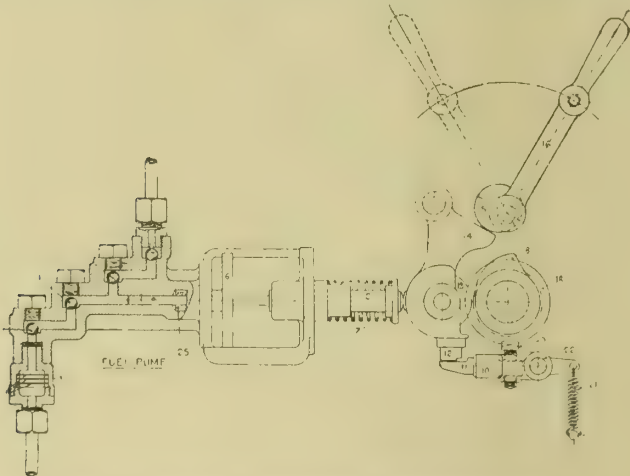


Fig. 34.—Section of Fuel Pump. Cross Oil Engine.

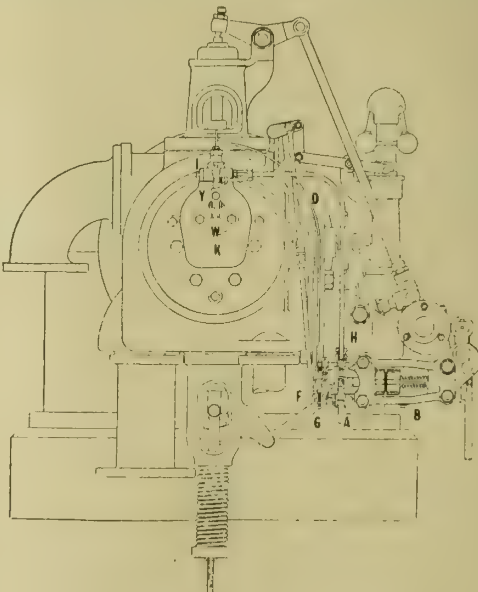


Fig. 35.—Ruston-Proctor Oil Engine.

is of small size, and only requires about three minutes to heat it by a blow lamp. These engines are built up to about 40 h.p. in four lines. The specific gravity of the oil used is 0·85. In this engine it is probable that a portion of the oil is exploded, followed by combustion. The engine may therefore be said to be partially of the explosion and partially of the combustion type, or, as they are sometimes called, of the semi-Diesel type.

The Ruston-Proctor engine is shown in Figs. 35 and 36, the last of which gives a section through the cylinder breach. Like the Diesel engine, it compresses pure air, but the compression, which is from 270lbs. to 280lbs. per square inch, produces a temperature insufficient to ignite the oil, and the necessary temperature has to be obtained by the addition of a hot bulb. This engine is, therefore, also of the so-called semi-Diesel type. The hot bulb is heated by a lamp to a dull red before starting, an operation which requires about 20 minutes, and it is maintained at this temperature during running by a water injection. The mean pressures obtainable are 84lbs. with crude oil, and 80lbs. with Italian refuse. The oil consumption is 0·45lb. and 0·49lb. per brake horse-power hour respectively, according to test made by Prof. Robinson on a 50 b.h.p. engine. A speciality of this engine is the way in which the fuel is injected: a needle valve is lifted by the action of the pressure produced by the oil fuel pump, and a swirling motion is given to the oil by means of a special device. The governor actuates a by-pass which opens the instant the necessary fuel has been injected, thus reducing the pressure and causing the needle valve to drop and shut off the oil.

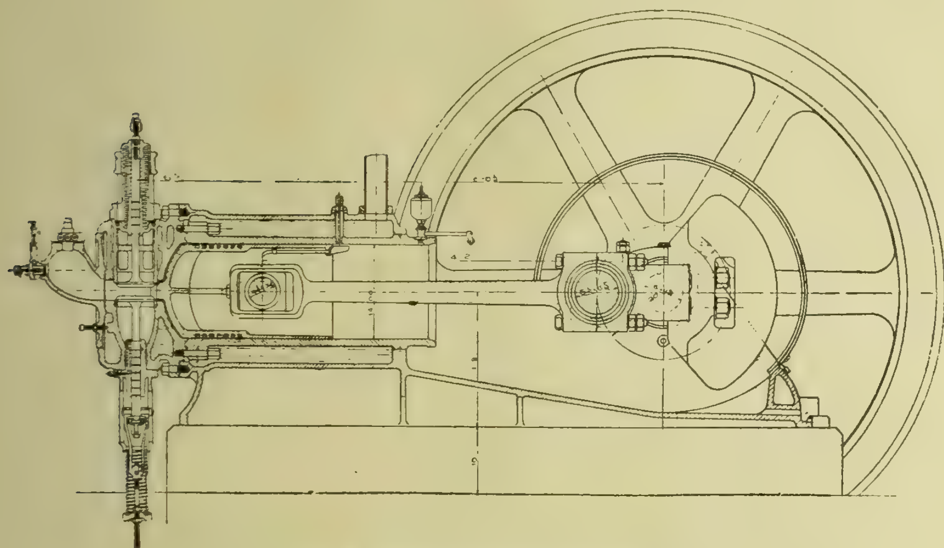


Fig. 36.—Ruston-Proctor Oil Engine.

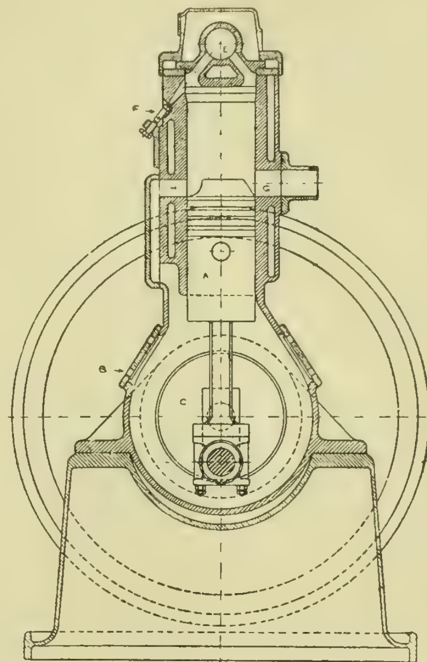


Fig. 37.—Bolinder Oil Engine.

The Petter engine is a 2-stroke engine of the semi-Diesel type. The scavenging air is compressed in the closed crank chamber on the down stroke of the piston. This air clears out the exhaust products, and on the up stroke pure air is compressed to a moderate pressure and the fuel oil is injected by a pump, and by a special arrangement is intimately mixed with the compressed air. These engines work with "fuel" oil of 0·93 sp. gr., and the consumption of oil of 0·93 sp. gr. is stated to be 0·47lb. per brake horse-power hour.

The Bolinder engine is of the explosion-combustion type; the makers, like many others, object to the name "semi-Diesel." Its action will be easily realised from Fig. 37. Just before the bottom of the stroke the exhaust valve G is uncovered, and almost immediately after the port H opens and admits the scavenging air compressed in the closed crank chamber by the descending piston which sweeps out the remaining products of combustion. By the special shape given to the top of the piston, this air finds its way into the hot-pot E, to clear out the exhaust products there. These engines are made in from one to four lines, and from 5 b.h.p. to 320 b.h.p. The consumption of Scotch shale oil varies from 1lb. to 0·6lb. per brake horse-power hour, according to the size of the engine. At heavy loads water is injected into the hot-pot to prevent it getting too hot, and thus "cracking" the oil. These engines are principally intended for the propulsion of small ships, such as fishing vessels, &c., and very large numbers have been supplied for these purposes. The reversal of the engine is effected by means of an apparatus diagrammatically shown in Fig. 38. There are two fuel pumps, the plungers of which are marked B and C respectively; A is the fuel pump; B is the normal pump worked by the pecker F actuated as shown in the figure. The full pump supply only comes into action when the direction of rotation of the engine is to be changed either from ahead to astern, or from astern to ahead. To change the direction of the engine from that shown by the arrow, the lever G is pulled over to the right; this brings the link K into contact with the friction wheel D and by means of the mechanism shown puts the pecker F out of action, bringing pecker T into action. The pump C is so timed as to inject the charge of oil before the piston reaches the top of the stroke; this checks the up stroke and drives the piston down in the reverse direction.

An engine has recently been proposed by Mr. Durtnall, which is of the Diesel type, but the suction valve is arranged

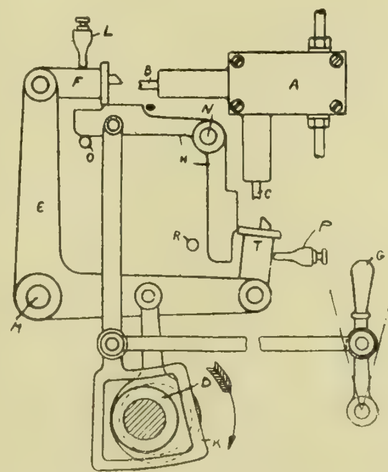


Fig. 38.—Arrangement for Reversing the Bolinder Oil Engine.

to close before the end of the out stroke, so that, as shown in Fig. 39, pure air is drawn in from A to B, and this air is expanded along the line B C to the end of the stroke at G. The reduction in pressure at the end of the stroke acts as an air cushion, arresting the motion of the parts and reducing the bearing pressure. On compression of the stroke the indicated diagram follows the line C B D, and the compression space in the cylinder can be so arranged that the pressure at D shall be 500lbs. per square inch needed for heavy oil ignition. D E shows the full admission as in a Diesel engine, and

the expansion E F G is extended to atmospheric pressure. The exhaust of this engine would therefore be at constant pressure. B D E F B would be the diagram of the corresponding Diesel engine. The theoretical thermal efficiency of

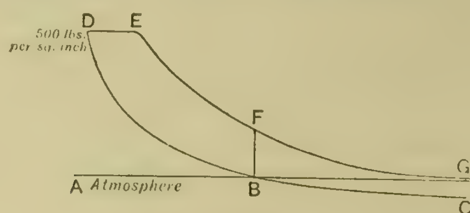


Fig. 39.

Heat Admission at		
Constant Volume.	Constant Pressure.	Partly Constant Volume and Pressure.
Explosive mixture is produced by vaporisation of the oil either at atmospheric temperature (light oils) or at a higher temperature (heavy oil)	Pure air is compressed in the cylinder, and the oil is introduced just before the turn of the stroke	
Compressed in the cylinder prior to explosion by a hot tube or bulb, or by an electric spark	Ignition is caused by the temperature of the compressed air	Ignition is caused by the oil striking against a hot surface
Compression limited upwards to avoid pre-ignition	Compression limited downwards to ensure ignition	Compression unlimited over considerable range
Low Compression	High Compression	Medium Compression
80 lbs. per square inch	500 lbs. per square inch	200 lbs. per square inch.
Sp. Gr. 0·68 to 0·72 | 0·82	Up to 1·2	Up to 0·9
< Light Oil Engines >	< Heavy Oil	Engines >

Fig. 40.—Chart Discriminating Between the Various Types of Light and Heavy Oil Engines.

this type of engine would therefore be greater than that of the pure Diesel engine.

In conclusion, the chart, Fig. 40, is given, discriminating between the various types of light and heavy oil engines.

Boiler Accident on a Warship.—Through the blowing out of a boiler head on board the U.S. battle-ship "Vermont" on November 1st, six men were more or less scalded, three of them so seriously that they died in hospital on the following day.

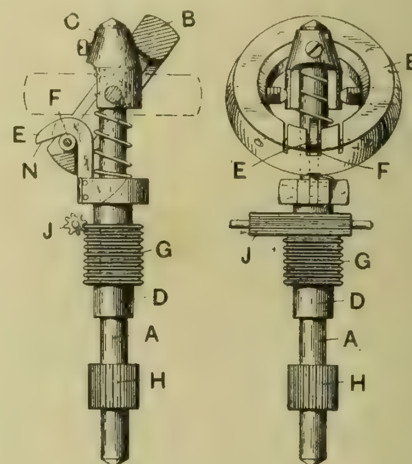
Flywheel Accident. — An accident occurred at Llanelly on the 8th inst. to an engine at the Burry tinplate works of Richard Thomas & Co., Ltd. The flywheel, weighing over 25 tons, burst and was hurled through the roof. One portion travelled 300 yards, and other pieces of the wheel fell dangerously near several houses. A girl was struck by a brick, but she escaped serious injury.

The Need for Closer Co-operation between Engineers and Architects.—At the opening meeting of the new session of the Royal Institute of British Architects, the president, Mr. Reginald Blomfield, speaking of steel construction, said Prof. Archibald Barr had called attention to the unfortunate severance of engineering from artistic design, and had said that the engineer took a too exclusively utilitarian view of his calling, and architects had not sufficiently mastered the science of steel construction to be able to design in it freely. He thought Prof. Barr was right, and the conclusion to be drawn was that in the modern practice of architecture the necessity of the study of scientific construction became more and more urgent. But he did not believe that the whole future of architecture rested with steel construction or reinforced concrete. Brickwork and masonry must always hold their place in buildings, and though architects would do well to avail themselves of all the resources of applied science there was no reason for throwing up their familiar tools and rushing headlong into methods, however their promise, which had not yet stood the test of time. While he heartily endorsed Prof. Barr's appeal for more thorough study of construction, and for closer co-operation between the engineer and the architect, he did not think that architecture was going to be stranded high and dry by the engineer.

CENTRIFUGAL GOVERNOR FOR SPEED INDICATORS.

The accompanying illustration shows an arrangement of centrifugal governor device for speed indicators, the joint invention of Messrs. S. Smith & Son, Ltd., 9, Strand, Westminster, and Mr. P. O. Dorer. Upon the spindle A is carried a ring B which constitutes the centrifugally-operated element. A support for the ring is provided by two pivots disposed across the diameter of the ring, the pivots being carried by a bell-like sleeve C rigidly connected to the spindle A. A sleeve D is mounted upon the spindle and is provided with a hook E rigidly secured to it, and which engages a pin provided with an anti-friction bowl F mounted in the ring B. Between the sleeve D and the bell-shaped sleeve C is a controlling spring in compression. The sleeve D carries a rack G, and is cut away as shown in order to balance the centrifugal action of the hook E which is mounted on that side of the sleeve. The spindle is driven by a pinion H, and the rack G engages a pinion J connected to the speed indicator pointer.

The operation of the device is as follows: When the spindle is revolved centrifugal forces tend to make the ring B assume a horizontal position, such as is indicated in chain line in Fig. 1. As the ring moves from the position of rest shown in full line, it carries with it the hook E, so displacing the sleeve D against the controlling force of the spring finally taking up some position intermediate



Centrifugal Governor for Speed Indicators.

between the position of rest and that shown in chain line. The condition of the sleeve D under the action of the force applied to the hook E and that exerted by the spring is one in which it is tilted, or tends to be tilted, owing to the want of lateral symmetry arising from the fact that only one hook is employed. The result of this is that frictional binding between the sleeve and the spindle tends to be produced, and would be unchecked if the cam-face N of the hook were at right angles to the spindle, and would be enhanced if the face N were upwardly sloped. By giving to the face N, however, a slight downward (as viewed in Fig. 1) slope, a force is introduced, by the action thereon of the pin on which the anti-friction bowl F is mounted, which counteracts more or less completely the tilting action, so reducing or eliminating the consequent binding effect. The reduction or removal of the binding effect has for its result a greater responsiveness in the indications of the instrument, that is to say, there is a less change of speed necessary to produce some movement of the sleeve D, since the latter is no longer held by the same frictional binding force, and does not therefore require the same force to be exerted before it will move.

Personal. — The London County Council have promoted Mr. G. W. Humphreys, the Deputy Chief Engineer of the Council, as from January 1st next to be Chief Engineer and County Council Surveyor at a salary of £2,000 per annum. There were 41 applications for the position vacant by the resignation of the late Chief Engineer, who left the service of the Council to start in private practice.

INDUSTRIAL AND TRADE NOTES.

A New Pump Valve.—The Dermatine Company, of 93 and 95, Neate Street, Camberwell, London, S.E., have just introduced a new valve called S.B. This is suitable where gritty or dirty water is met with, and is of particular interest to engineers of water works and others in charge of deep well pumps. The company will be pleased to send full particulars to engineers, &c.

Light Railway.—The Board of Trade have recently confirmed the under-mentioned Order made by the Light Railway Commissioners: East Kent Light Railways (Extensions) Order, 1912, authorising the construction of light railways in the county of Kent, from Wingham to Stodmarsh, and from Great Mongeham to Ripple, in extension of the light railways authorised by the East Kent Light Railways Orders, 1911.

Scottish Blastfurnacemen's Wages.—As a result of the report by Mr. John M. MacLeod, C.A., Glasgow, to Messrs. Jas. C. Bishop and Jas. Gavin, joint secretaries of the Board of Conciliation between the owners of blastfurnaces in Scotland and blastfurnacemen as to the price of Scotch pig-iron warrants in the Glasgow market for the months of August, September, and October, 1912, there is a rise of 10 per cent. in the wages of the workmen.

Meldrum Bros., Ltd.—The works and assets of this company at Timperley, Cheshire, which, with the goodwill, for two or three years have been in the hands of a liquidator, have together been transferred to a new company, formed for the purpose, which will continue the business under the style of "Meldrums, Ltd.," of which company Mr. John W. Meldrum, who has been manager during the liquidation, will be the managing director.

Scottish Ironmoulders' Wages Increased.—An adjourned conference between representatives of the National Light Casting and Ironfounders' Federation, the Associated Ironmoulders of Scotland, and the Central Ironmoulders' Association was held on the 28th ult. at Glasgow, to consider the claim of the men for an increase of wages. After an exchange of views extending over five hours the conference agreed that there should be an increase of wages to the extent of 2½ per cent., beginning from February 3, 1913.

Appointment of H.M. Trade Commissioner for Australia.—The President of the Board of Trade has appointed Mr. G. T. Milne to be H.M. Trade Commissioner for the Commonwealth of Australia, in succession to Mr. C. Hamilton Wickes, who has been transferred to Canada. Mr. Milne is at present completing an enquiry, on behalf of the Advisory Committee to the Board of Trade on Commercial Intelligence, into the conditions and prospects of British Trade in Central America, and will proceed to Australia early next year.

An Oil-Tanker Boom.—It is estimated that 115 oil-carrying ships are now under construction in this country and abroad. The demand, in fact, is so great that the firms who specialise in this class of work are only accepting contracts for delivery a long time ahead. Owing to the impossibility of obtaining prompt tonnage for the conveyance of petroleum and other liquids in bulk, some owners are, we learn, buying ordinary cargo boats for conversion into tankers. The Admiralty, which already owns three oil-carriers, has ordered another four to be built, all to be fitted with internal-combustion engines, which will be built at Barrow and at Cowes.

Shot-firing in Mines.—In view of representations which have been made to the Home Office on the subject of the prohibition of squibs for the purpose of firing shots in coal mines where safety lamps are not required to be used, the Home Secretary has appointed a committee to enquire and report on the matter, and particularly as to whether the use of squibs in these mines is attended with such special danger as to make it desirable that this method of firing shots should be prohibited, and, if not, whether any special conditions in regard to the manufacture and use of squibs should be laid down. The committee consists of Mr. H. Johnstone (inspector of mines for the Midland and Southern Division), Mr. A. M. Lamb, and Mr. S. Walsh, M.P.

Proposed New Mining Laboratory for Edinburgh.—A proposal is under consideration to erect a new mining laboratory in connection with the Heriot Watt College, Edinburgh. Mr. Briggs, the mining lecturer at the College, in a report on the scheme, urges the need for a university degree in mining in Edinburgh. A three years' mining course, whether for diploma or degree, cannot be held complete without the metalliferous branch being studied as well as that of coal. Experience has shown that there is a considerable demand for training in metal mining in Edinburgh. It is remarkable that at present there is no institution in the East of Scotland in which metallurgy is taught. The full scheme makes provision for the following rooms: Coal mining laboratory, two gas testing laboratories, research laboratory, metallurgical laboratory, micrographic, section cutting, and photographic rooms, drawing office, rescue apparatus room, lecturers' private rooms and office, museum and library, metallurgical and mining lecture theatres, central machinery hall and ore dressing and coal-washing laboratories.

International Exhibition at Ghent.—Particulars of the spaces taken by the various countries officially exhibiting at the International Exhibition at Ghent, 1913, have just been announced by the Belgian authorities. The British pavilion has an area of 161,000 sq. ft. Of this space, 90,000 sq. ft. is to be filled with a display of textile machinery and machine tools, while the remainder is taken up with an exhibit of arts and crafts, pottery, and a display by the British Government. The organisation of the British section is in the hands of the Exhibitions Branch of the Board of Trade, Queen Anne's Chambers, Westminster, S.W. The Canadian pavilion has an area of 86,000 sq. ft. The official French pavilion is over twice the area of the British, and French firms have between them taken a still larger area, the total reaching 860,000 sq. ft., or nearly 20 acres. The German exhibit is to be housed in a special pavilion of modern and striking design, and will occupy 150,000 sq. ft. Belgium, of course, has taken a large amount of space. The whole exhibition covers roughly 250 acres, which is 50 acres more than the great exhibition at Brussels in 1910.

Co-operation in Commercial Development.—In the last report of the colonial series recently issued, dealing with the work during 1911 of the Imperial Institute, the director reports continued progress in those special commercial investigations, especially of new sources of raw materials, which, while primarily conducted for the Dominions and Crown Colonies by the scientific and technical staff of the Institute, are also of material assistance to the British manufacturer and merchant. The mineral surveys instituted and supervised by the Imperial Institute are an important branch of its work, and have yielded valuable results to both commerce and science. In Southern Nigeria the mineral survey has been the means of revealing the sources of fuel which, it is hoped, will be of immense value to the whole of West Africa, and the reports show that the work of the Imperial Institute has brought the matter well within the sphere of commercial enterprise. With the sanction of the Foreign Office, a mineral survey has also been organised in the territories of the Mozambique Company, in Portuguese East Africa. The scientific and technical department of the Institute works in co-operation with the mines departments in the Colonies, whose operations it supplements by undertaking investigations and enquiries of a special scientific and technical character connected with mineral development.

Disputes in the Engineering Trade.—At a meeting of the Industrial Council, held on the 6th inst. in London, Sir George Askwith presiding, evidence was submitted on behalf of the employers by Mr. Allan M. Smith, secretary of the Engineering Employers Federation. Replying to Sir George Askwith on the question of the advisability of the introduction of a third party in the matter of a trade dispute, he said he had no desire to minimise the usefulness of outsiders, but the Federation held very strongly to the view that, if they would come to an agreement with the unions representing their workmen, there was a very much greater chance of their arriving at an harmonious conclusion than if an outsider came in, on the ground that family quarrels were best settled without outside interference. He opposed the suggestion that difficulties should be settled by arbitration. There had hitherto been no difficulty in getting either side to meet the other, except in one or two isolated cases where the old system was still in vogue, and the employer did not desire to deal with trade unionists. Agreements were not arrived at in a hurry. He knew of cases where agreements had taken seven years in the making. There was machinery in existence for the avoidance of disputes, and this resolved itself into—first, a conference between the masters and the men's section; second, a meeting between the Federation and the trade union officials; and, third, if no settlement had been arrived at the question in dispute must be referred to the central authority of the Federation. This procedure was a necessary preliminary, and stoppage of work before it had been carried through constituted a breach of agreement, but at the conclusion of the complete procedure the contending parties could take what action they chose. He did not think any industrial agreement would be satisfactory under any circumstances unless there was some agreement that they were compelled to discuss prior to any extreme step. In the event of such a breach of agreement a monetary penalty should be imposed at the rate of so much per man per day so long as the strike lasted. He submitted that the enforcement of industrial agreements by criminal process had not proved a success, but such enforcement by civil process did not present the same difficulties. A most important consideration in organisation was the subjection of the individual to the discipline of the governing body, and it was suggested that both the employers and workmen should be responsible through their respective organisations.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Mechanism for the starting with compressed air of multi-cylinder internal-combustion engines. Marks 18665.
Heat-storage devices. British Thomson-Houston Company. 18676.
Rotating cutter machines for shearing metal. Hendee. 18694.
Gear-cutting machines. Darling, Sellers, & Spencer. 19145.
Manufacture of steel sheets for use in making tin plates. Bevan. 23002.
Vapour burners for steam generators. Galvao. 23132.
Internal-combustion engines. James, Orr, & Maude. 23332.
Draught-regulating devices for fire-tube boilers. Schulz. 23352.
Manufacture of steel. Wilmot. 23526.
Turbines. London. 23634.
Propulsion of vessels. Thornycroft, and John I. Thornycroft and Co. 23746.
Pneumatic railway signalling systems. Glenn. 23818.
Apparatus for treating gases and vapours with liquids. Fowler and Medley. 23864.
Devices for grinding circular cutters having a plurality of cutting blades. Jerram, and British United Shoe Machinery Company. 23939.
Testing or gauging attachment for use with scribing blocks or calipers. Grant. 23947.
Valves with two or more seats. Romanowsky. 24231.
Vane wheel pump. Wachter. 24483.
Method of and means for removing fallen sand from or for cleaning moulds prior to casting. Lockart. 24845.
Means for cooling internal-combustion engines. Weller. 25504.
Vaporisers for internal-combustion engines. Dawson. 26385.
Rotary engine. Lewis. 26583.
Valve mechanism. Marks. 27901.
Ship propulsion. British Thomson-Houston Company. 28512.
Mechanical or power-actuated hammers. Blacker. 28656.

1912.

Centrifugal compressors. British Thomson-Houston Company. 1497.
Acetylene generators. Byrne, Lawrence, and Howes & Burley, Ltd. 2333.
Apparatus for vaporising fuel for internal-combustion engines. Constantinescu. 2870.
Screw-cutting gear for turret lathes. Ludw. Loewe & Co., Akt.-Ges. & Sauer. 4778.
Manufacture of seamless tubing. Pittsburg Steel Products Company, Brock & Selkirk. 4793.
Manufacture of twist drills. Spencer. 5074.
Superheaters. English, Mills, & Hannan. 6056.
Nut-locking device. Martinez. 6144.
Steam superheaters. English, Mills, & Hannan. 6692.
Regulation of continuous combustion internal-combustion engines. Otten. 6777.
Rotary engines and pumps. Ogden. 6789.
Speed-regulating device for hydraulic motors. Schwier & Schien. 7601.
Gas turbines. A. Horch et Cie Motorwagenwerke Akt.-Ges. 8131.
Wrenches. Vinton. 8401.
Revolving chain grates. Bennett & Smith. 9300.
Working of metal. British Thomson-Houston Company. 9877.
Screw propellers. Blake. 10157.
Simplified method of cooling pistons of internal-combustion engines. Sheppard & Sheppard. 10314.
Reversing gear for internal-combustion engines. Kylliainen. 10648.
Apparatus for injecting fuel in internal-combustion engines. Franke. 10707.
Self starting devices for internal-combustion engines. Lomas and Willison. 12269.
Automatic stop valves. Aagaard. 14506.
Rotary internal combustion motors. Bose & Faligant. 14623.
Steam generators. Steinmüller. 15042.
Instrument for converting measurements. Conti. 15143.
Nut locks. Edwards. 15491.
Windmills. Lowe. 15668.
Propellers. Kornmann. 16668.
Steam turbine plant for working with live and exhaust steam. Vereinigte Dampfturbinen Ges. 16710.
Pilot valve arrangements for fluid pressure controlled valves. Lake. 16897 and 16898.
Ball and disc variable speed mechanism. Pollen & Isherwood. 17441.
Adjusting the friction drive of fans for air-cooled motors. Warrick. 17809.
Conveyer-belt for pulverised materials. Garelly. 19045.
Safety screw and nut. Itschner. 19062.
Aeroplanes. Esnault-Pelterie. 20927.
Carburetters for internal-combustion engines. Torrens. 21588.
Carburetters or vaporisers for internal-combustion engines. Torrens. 21589.

ELECTRICAL, 1911.

Electric switches. White. 9686.
Compensation of polyphase commutating dynamos. British Thomson-Houston Company. 16737.
Operation of electrical machines of the induction type. Price. 20709.
Dynamos. Clarke. 22987.
Semi-automatic telephone exchange systems. McBerty. 23508.
Automatic electrical signalling systems for railways. Hawkes and Cleburne. 23846.
Electric water heaters. Nichols. 24445.
Electrically-driven planing machines and similar reciprocating tools. Vickers, Ltd., and Williamson. 25459.
Process for carrying out gas reactions in an electric furnace. Helfenstein. 26371.
Apparatus for heating, evaporating, volatilising, or distilling liquids by electricity. McClelland. 27422.
Electrical accumulators. Smith. 27542.
Inter communicating telephone systems. Fairweather. 28165.

1912.

Electrical switches and fuses combined. Bill. 30.
Electric current or energy measuring instruments. British Thomson-Houston Company. 1079.
Manufacture of electrodes for galvanic batteries. Wedekind. 1198.
Starting switches for rotor circuits of alternating-current motors. Shaw & Shaw. 1449.
Electric lighting systems for automobiles. Bijur. 1753.
Electrical heating and radiating apparatus. Martin. 2764.
Telephonic transmitters. Struxiano. 6393.
Galvanic batteries. Banks & Wood. 6758.
Electrical cut-in and cut-out devices for use in charging accumulators. Leitner. 7572.
Electric incandescent lamps. Hewitt. 8086.
High-speed rotors for high-frequency multipolar electrical machinery. Goldschmidt. 10507.
Current interrupter for high tension lines. Clar & Clar. 12320.
Electrically-controlled signals for use in determining temperature. McNab. 14653.
Wave detectors for radio telegraphy and telephony. Thibault. 16163.
Receiving apparatus for electric waves. Schneider. 18188.
Electric mercury motor meters. Gottschalk, and H. Aron Elektricitäts-zählerfabrik Ges. 18810.

METAL QUOTATIONS.

TUESDAY, NOVEMBER 12TH.

Aluminium ingot	85/- per cwt.
" wire, according to sizes, &c. ......from	112/- "
" sheets " " ...... "	120/- "
Antimony ......£38/-/- to	£40/-/- per ton.
Brass, rolled	9⅛d. per lb.
" tubes (brazed)	11½d.
" " (solid drawn)	9¾d.
" " wire	9⅛d.
Copper, Standard	£76/7/6 per ton.
Iron, Cleveland	66/9 "
" Scotch	72/9 "
Lead, English	£19/-/- "
" Foreign (soft)	£18/7/6 "
Mica (in original cases), small	6d. to 3/- per lb.
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£7/12/6 per bottle
Silver	28⅞d. per oz.
Spelter	£27/5/- per ton.
Tin, block	£227/5/- "
Tin plates	15/6 "
Zinc sheets (Silesian)	£31/5/- "
" (Stettin; Vieille Montagne)	£31/10/- "



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Efficiency Tests of Air Compressors.

In his paper before the Manchester Association of Engineers on the 9th inst., Mr. George Barr rendered a useful service in calling attention to the somewhat careless and inaccurate methods in which guaranteed performances of air compressors are measured and the misleading nature of many of the so-called efficiency tests. In respect to efficiency this class of machinery has, it should be noted, laboured under a bad reputation. "Give a dog a bad name and hang it" would seem to be an adage that could be very pertinently applied. Many old steam-driven machines undoubtedly deserved this reputation. They were of horizontal design, cylinders were arranged in tandem with the air cylinders, which had no water jackets and depended simply on spray cooling arrangements, piston speeds were low, seldom exceeding 300ft. per minute, valves were heavy, clearance spaces were large, and the compression was effected in a single stage. Contrasted with really high-class and well-thought-out machines, such designs were lamentably antiquated, and there is all the difference in the world between the efficiency of such a plant as compared with one of vertical enclosed design, forced lubrication, water-jacketed cylinders and a piston speed of 500ft. to 600ft. per minute, with clearance spaces down to 2 or 3 per cent., and 2-stage compression for pressures from 70lbs. to 100lbs. As an illustration of the difference which may exist, Mr. Barr gives an instance where a well-designed machine with four times the capacity replaced an old machine and yet required only the same amount of steam. It appears probable, too, that instances where such improvements might be effected are by no means rare, and that advantage is not taken of this possibility is due to the rather general impression that nothing but inefficiency with such plants can be expected. One regrettable consequence of this has been to generate a degree of slackness in respect to tests demanded in connection with their installation, and it is scarcely a matter for surprise that a

considerable amount of ignorance prevails as to the value of such tests and the way they should be made. It is not unusual to find even enquiries issued for large compressors accompanied merely with statements as to the capacity of the machine, pressure, and vacuum mentioned, if steam driven, or voltage, if operated electrically. On rare occasions is steam consumption asked for and rarer still is a capacity test required, while such a test when made is seldom any check on the output of the machine, since it is generally supposed to be complied with by filling a reservoir of given capacity from atmospheric pressure to final working pressure. Temperature may or may not be taken, but if it is, it is generally misleading and easily allows of errors up to 10 per cent. Indeed, it is questionable, if we accept Mr. Barr's statements, and they appear to be based on extensive experience, "whether there is at present any compressor at work, the actual capacity of which is known correctly through a test." This is a rather strong indictment, but he offers good ground for it. As an actual example of testing practice, he cites the case of an electrically-operated up-to-date plant where a supposed volumetric test was called for in the enquiries issued, with information as to amount of current, size of air cylinders, stroke, revolutions, &c. In the test, receivers of known capacity were used, note was taken of the revolutions required to do this, as well as of the temperature of air inlet and receiver, and everything was passed as satisfactory. Yet it requires little consideration to recognise that the volumetric efficiency of a compressor may vary greatly between atmospheric and working pressure, and that a test, to give reliable and comparative figures, should be made with the machine discharging against a constant working pressure during the whole run, whereas the test as carried out did not even take note of the fact that the receiver was actually filled with one volume of air to begin with. Errors from these two sources alone might easily disturb results to the extent of 12 per cent., and with possible errors in temperature readings might increase this to even 20 per cent. It is not so much the ignorance of engineers respecting these disturbing influences as the carelessness which has crept into specification standards regarding air compressor performances to which Mr. Barr calls attention and against which he protests, not only in the interests of makers, but of users who seek good designs and high efficiency, and it is from this point he discusses the question as to what is a reasonable test such, for instance, as would permit of results being expressed within a limit of error of 5 per cent. for imperfections in readings of temperature, speed, pressure, &c. To this end it is necessary to decide in the first place whether the test is to be made at the inlet or the discharge of the machine. Provided both could be made with equal accuracy and simplicity, there is nothing to choose, and hence it is desirable to consider which side is likely to introduce the greatest chance of error. If the discharge be chosen, it is pointed out a large receiver capacity is desirable to eliminate errors in counting speed, while barometer as well as temperature readings should be taken, careful measurements made of the volume of receiver, pipes, and connections, and any collected water which might be serious in amount drained away, such a test being supplemented with a static test on a time base to note drop in pressure and so measure leakage. Without going into refinements, it may be stated that such a test, even with care, permits of certain errors creeping in from which a test on the inlet side is free, though in practice the latter is more difficult to carry out. In the first place, the estimation of the volume of air flowing through an orifice requires delicate anemometer readings over the area and somewhat costly apparatus if it is to be made correctly. Granted, however, that it is available, readings may be made within an error of 2½ per cent. and, coupled with a careful record of temperature and barometric pressure at the inlet, give all the data necessary for correct estimations of volumetric efficiency. This does not of course imply that the machine is the best design. Its mechanical efficiency may be low from restricted air passages, ineffective cooling arrangements, &c., and vice versâ a machine may excel in these points to begin with and yet fail to maintain it through defective design. What the user, after all, really wants is a compressor which requires only a small amount of power for a given quantity of air delivered, and Mr. Barr suggests that a definite quantity, say, 100 cub. ft., delivered against a definite pressure, say, 100lbs. per inch, for a certain expenditure of power might be taken as a standard total efficiency, which would include mechanical efficiency, volumetric efficiency, losses in compression, &c., and, taking present types on the market, such a figure as 20·5 electrical horse-power might reasonably be expected, with a 2-stage compressor, to cover 90 per cent. motor efficiency, 90 per cent. mechanical efficiency, and 80 per cent. compressor efficiency, and be fairly equivalent to 20 h.p. in a steam-driven machine. Mr. Barr's suggestion has much to recommend it, and its adoption would certainly lead to a more scientific conception of air compressor efficiency than that which now prevails among users and makers of air compressing machines.

THE APPLICATION OF CO_2 TO REFRIGERATION.

AT a recent meeting of the Junior Institution of Engineers a paper was read by Mr. A. H. Tyler on the above subject, in which he cautioned those reading up the subject to carefully investigate the basis of any published figures. Any figures bearing the name of Dr. R. Hollier could be trusted. The title of CO_2 was examined, together with the source of supply, and who the chief consumers were. It was pointed out that CO_2 had much to recommend it as a refrigerating medium, as it was inexpensive, generally obtainable, and safe to handle, being inodorous and harmless. The specific gravity of CO_2 was touched upon, and a table of the properties of CO_2 (carbon dioxide) was given; the critical temperature being dealt with fully, a further table being quoted. A diagram of the entropy of CO_2 was shown, and the factors that go to make up efficiency and range were given. In describing the types of compressor and efficiency, several tables and figures were quoted, and the author said that the more generally-known type of CO_2 compressor was the double-acting leather-packed compressor, such as was generally used for marine purposes. This type had prevailed on account of the commercial points in its favour, and in spite of its low efficiency. The results of an interesting series of experiments on frictional losses in power to drive compressors were given; and for the effect of range on power consumption at different ranges the power required was obtained by multiplying the power by the brine percentages, such as shown on the set of curves set out in the paper, which gave the percentages for all brine temperatures from 45° to 0° Fah., and condensing water temperatures from 55° to 90° Fah. With regard to two-stage compressors, very divergent opinions existed among the leading designers of CO_2 compressors as to the advantages to be gained by compressing in two stages instead of one, but generally speaking there was no advantage to be gained by using two-stage compression when the range of temperature was less than 50° Fah., or for machines of less than 20 tons refrigerating power. The paper concluded with a full consideration of wet and dry compressions, and of the minor advantages of CO_2. A discussion followed the reading of the paper, in which Messrs. H. E. Newton, W. Stokes, D. N. Hunt, A. J. Ball, T. J. Tapling, G. C. Hodsdon, and W. S. Douglas took part, and a hearty vote of thanks having been accorded the author, the meeting terminated.

Fatal Boiler Explosion near Paris.—A boiler exploded in a dyeworks in the suburb of Vitry on Thursday last week just when the workmen were returning to work. One man was killed outright and six were very seriously injured, while a score more were hurt but not so badly. Three of the injured have since died, and the lives of two others are despaired of.

ROBINSON'S PISTON VALVE FOR LOCOMOTIVES.

THE accompanying illustrations show two designs of piston valves for locomotives, the invention of Mr. John G. Robinson, "Boothdale," Fairfield, Manchester, Fig. 1 being a sectional elevation of the complete valve portion of the piston valve arranged for inside steam admission, and Fig. 2 a section of one end of a piston valve arranged for outside steam admission.

Referring to Fig. 1, A is the piston valve spindle and B is the liner of the valve casing or chamber in which are provided the usual ports C for the admission and exhaust of steam to and from the engine cylinder, D being the port for admission of steam to the piston valve chamber. The main portion of the valve comprises a wrought-iron or mild-steel tubular stem E divided across the middle, there being provided at the outer end of each tubular part of the stem E a relatively thin or light disc F formed integral with the tubular stem E, a tubular boss being provided on the outer face or side of each of the discs. G is the outer wrought-iron or mild-steel cap of the valve having an inwardly projecting tubular boss adapted to abut against the tubular boss on the disc F. The tubular stem E and cap G are keyed upon the spindle A. They are also held against displacement longitudinally on the spindle by means of a nut H. J is the cast-iron packing ring, K the cast-iron following or exhaust ring, and L is the distance ring situated between the disc portion F and the cap G. The transversely split or packing ring J has an inwardly projecting circumferential flange which abuts the outer face of the disc F. Semi-circular grooves U are cut in the outer periphery of the packing ring J, which is split transversely in the manner shown at M, provision also being made by shaping or cutting two semi-circular grooves for the insertion of a pin N by means of which the packing ring J is retained in position. The transversely split or spring follower ring K is provided with a shouldered portion which abuts the inner face of the end cap G. Into the recess formed by this shoulder the outer portion of the packing ring J fits and the two rings J and K are of a suitable width to just fit between the disc portion F and the end cap G when placed in position. The follower ring K is split at O, as shown, a circular hole being cut in this ring for the insertion of the head of a pin or stop P, so as to prevent displacement. L is an unsplit, continuous or solid ring of a slightly smaller diameter than the inside diameter of the spring ring J, so that an annular space T is formed between the rings J and L and the latter ring is of such a width that it fits closely between the flange portion of the ring J and the inner face of the follower ring K. The pin N is screwed into the ring in such a manner that when the packing rings J, K, L are in position the stop N will engage with the grooves in the packing ring J. S is a circular hole drilled in the inwardly projecting flange of the ring L and is of such a diameter that the end of a stop R will enter and engage with the hole S when the parts of the valve are assembled. The pins P and R are screwed into the end piece G in such a position that when the follower ring K and the solid ring L are in position the pins P and R engage with the holes respectively in the follower ring K and solid ring L and effectually secure them against displacement. The pin N in the solid ring L engaging the grooves in the ring J acts to hold the packing ring J against displacement. By this means circumferential displacement or rotation of the rings J, K, L are prevented and consequently the joints in the rings J and K are prevented from coming into line and are thus retained over the bars in the liner B of the valve chamber or casing.

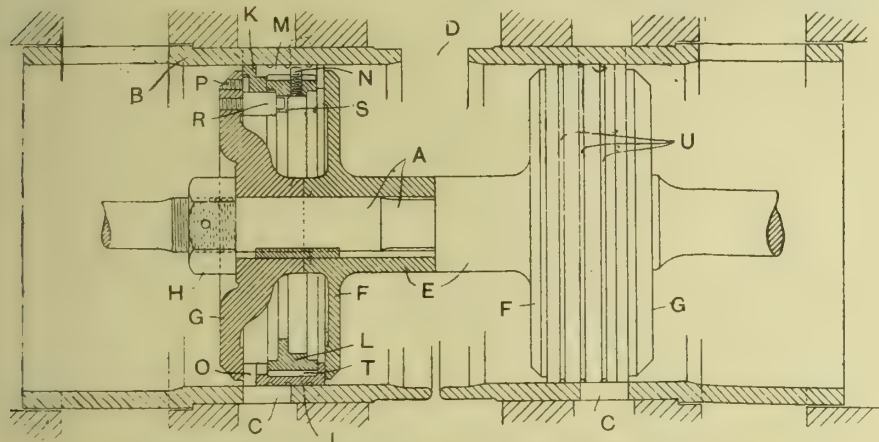


FIG. 1.—ROBINSON'S PISTON VALVE FOR INSIDE STEAM ADMISSION.

Referring now to Fig. 2, which shows one end of a piston valve arranged for outside steam admission, it will be seen that the relatively light or thin disc F is secured on the outer end of the valve spindle so as to be under the influence of the steam admitted to the steam chest through the port D. C are the ports for admission and exhaust of steam to and from the engine cylinder. G is, in this case, an inner relatively thick and rigid disc formed integrally with the tubular stem E. The arrangement and construction of the packing ring J, the follower or exhaust ring K, and the distance ring L are substantially the same as described and illustrated in Fig. 1, the flanged portion of the packing ring J being, in this case, arranged to abut the inner face of the end disc F, the rings K and L being arranged accordingly. The construction and arrangement of the packing rings J, K, L, and the diaphragm F and end cap G of the valve are such that while the packing rings are relatively light, consistent with the necessary strength, substantial or maximum driving areas or faces are provided on the rings (as it will be seen that the major portions of the depth or thickness of these rings are employed as driving surfaces) whereby easy working is obtained, and wear of the faces of the packing rings and of the liner is considerably reduced, and consequently the accuracy of the valve edges regulating the admission and exhaust of steam is maintained for a relatively long time, thus rendering the valve more efficient. As the discs F, and caps G, and valve stem E can be made of mild steel, a relatively light valve is obtained.

The steam enters through the port D and exerts a pressure upon the discs F of the valve and this pressure is always maintained while steam is being passed to the cylinders. Owing to the discs F being made of a relatively light section they have, under the action of the steam pressure, a tendency to press the rings J and K against the caps G, thus helping to make a good tight joint. When the spring or split packing ring J passes over the ports D of the valve casing liner B steam is admitted through the grooves U in the ring J, through the transverse split portion M, into the annular space T, and causes the split ring J to be expanded or pressed outwardly so as to make an efficient steam-tight joint with the valve seat or liner B of the valve chamber. When steam is shut off from the valve chest the packing ring recedes from the liner, thereby reducing friction and wear to a minimum.

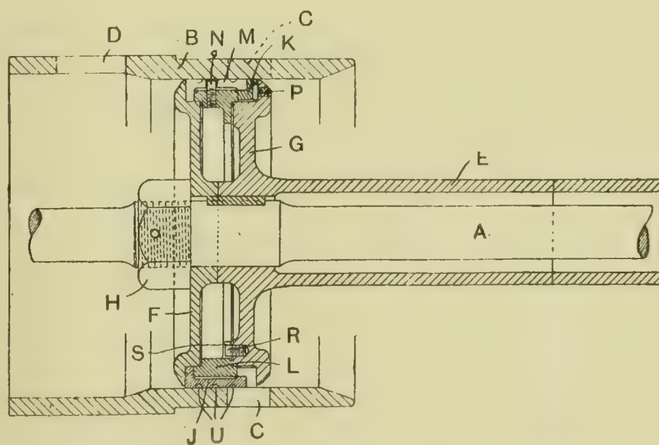


FIG. 2.—ROBINSON'S PISTON VALVE FOR OUTSIDE STEAM ADMISSION.

A feature of the valve under notice is that it is simple in construction and, it is claimed, more efficient in action than valves of a similar type heretofore employed. The employment of cast-iron packing rings provides the best medium for withstanding the exceedingly high temperature of the steam as used with present-day engines.

AIR IN SURFACE CONDENSATION.*

BY GEO. A. ORROK.

In the paper on "The Transmission of Heat in Surface Condensation†," the subject of the effect of air on vacuum and heat transference was considered and reference was made to the few authorities who had investigated this subject. The author was unable to find that anyone had quantitatively measured the air in a condenser, except J. A. Smith who had introduced known quantities of air and noted the effect on vacuum and heat transference.

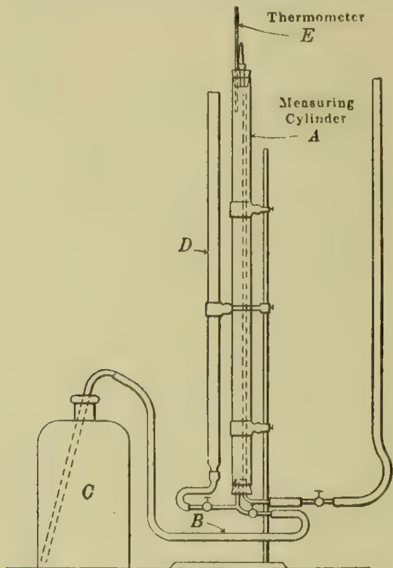
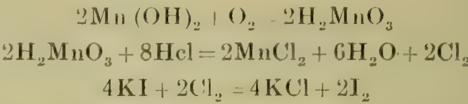


FIG. 1.—APPARATUS USED TO DETERMINE AMOUNT OF AIR MECHANICALLY ENTRAINED IN WATER.

In view of the lack of knowledge of this subject the author determined to investigate: (*a*) The amounts of air contained in feed-water and those entering the condenser through the prime mover. (*b*) The amounts of air removed from the condenser by means of the air pump. (*c*) The effect of known quantities of air on the action of a surface condenser of commercial size.

The problem of air in the feed water has been investigated by Smith, whose paper appeared in "Engineering," October 7th, 1904. He gives a table showing that the gases present in various samples of fresh and salt water varied from approximately $\frac{7}{10}$ of one per cent. to as much as $3\frac{1}{2}$ per cent. by volume. He also investigated the emission of gas from water when heated to about the boiling point, and gave figures and curves showing his results.

The author's investigations were made at the Waterside No. 2 station of the New York Edison Company, and the water samples were taken both from the suction and discharge sides of the feed pump. The average temperature of the feed water during the tests, after having passed the heater, was about 190° Fah. It was thought possible that there might be air bubbles mechanically entrained in the water, besides the amount of air in solution. To determine the amount of this entrained air samples of the water were allowed to flow through the apparatus which is shown in Fig. 1. The water entered through the tube F and passed to the top of the measuring cylinder where the air separated and was collected at the top of the cylinder; the water flowed out of the cylinder through the tube B into the glass demijohn where it was measured. These tests were started with the apparatus entirely filled with water. The air collected was measured at atmospheric pressure by means of the pressure-regulating cylinder D. The temperature of the air was determined by the thermometer E. The amount of air dissolved in the feed-water was determined chemically by means of the following reactions:—



$$2Mn(OH)_2 + O_2 = 2H_2MnO_3$$

$$2H_2MnO_3 + 8Hcl = 2MnCl_2 + 6H_2O + 2Cl_2$$

$$4KI + 2Cl_2 = 4KCl + 2I_2$$

The free iodine liberated was titrated with a solution of sodium thiosulphate of known strength and its amount determined. From this amount the quantity of oxygen in solution in the sample of water taken was calculated. The amount of air in solution was then figured from the known ratios of oxygen and nitrogen in solution in water at various temperatures. The determination in this way may be considered quite accurate. This determination of air in water was also made of a number of samples of Croton water (the make-up feed) and from hot-well water. The following results, in per cent., were obtained of air by volume at atmospheric pressure:—

	187° Fah.
Mechanically entrained in feed water, average of ten tests...	0·0151
In solution in feed water, average of ten tests.................	0·916
Total air in feed water from open heaters........................	0·931
	52° Fah.
In solution in Croton water, average of three samples......	4·325
	80° Fah.
In solution in hot well water, average of four tests...........	0·269

These results show that Croton water gives off most of its dissolved air in passing through the open heaters, the amount of air occluded in the feed-water (0·931 per cent.) being comparatively small. At 81° Fah. and 2in. of mercury absolute pressure when saturated with water vapour, this amount of air would occupy only $\frac{1}{17}$ of the volume of the condensed steam. The results obtained accord well with reports from other sources, although the author could find but little quantitative information on the subject. The fact was established, however, that very little air came into the condenser from the feed-water.

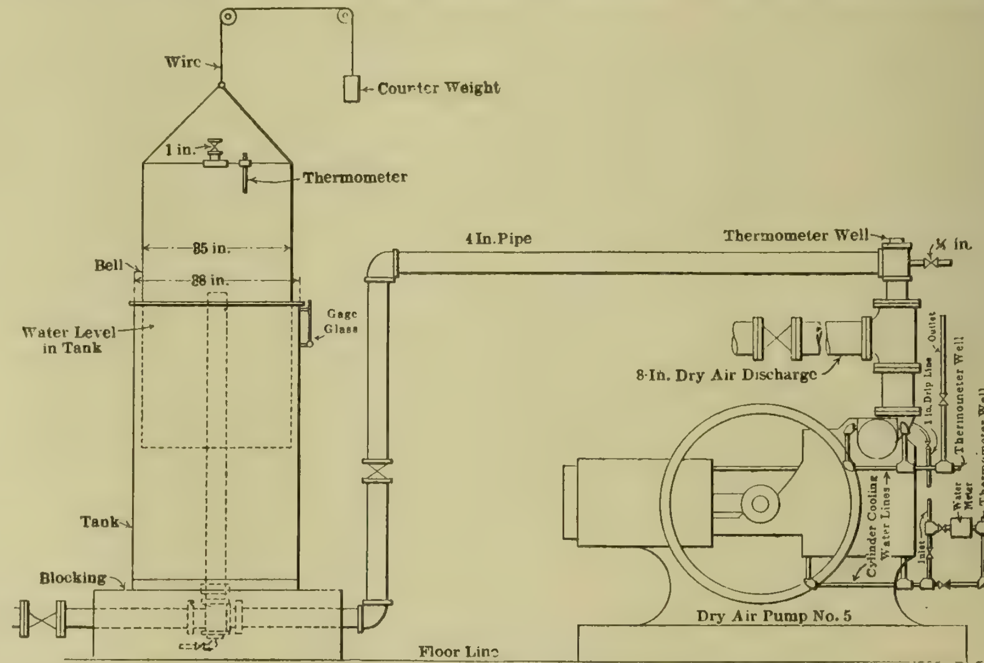


FIG. 2.—LAY-OUT FOR MEASURING AIR DISCHARGED BY DRY VACUUM PUMP.

Having obtained the portions of air which enter the prime mover along with the steam, the next object of investigation was to determine the amount of air abstracted from the condenser by the air pump. Here again there were no precedents, but it was determined to catch the air over water in a gasometer. For this purpose the discharge pipe of the air pump was piped to a gasometer bell located in the basement in the vicinity of the air pump. A sketch plan of this outfit is shown in Fig. 2. After the air pump had been

* Paper read before the American Society of Mechanical Engineers.
† Trans. Am. Soc. M.E., Vol. 32, p. 1139.

running for a sufficient time to make sure that the conditions were constant, the valve was opened and the discharge from the air pump was allowed to enter the bell allowing it to rise. The time required to fill the bell was noted with a stop watch and from these data the amount of air delivered was calculated. The air in the bell was brought to atmospheric pressure and temperature before the final readings were taken. Other tests were made with the pump shut off from the condenser to determine the air leakage in the pump itself and also with the suction piping blanked off at the condenser to determine the pipe leakage.

TABLE I.—*Results of Tests on Dry Air Pumps for Surface Condensers.*

Number of Tests Made	Date of Tests	Load on Turbine, Kw.	Vacuum at Top of Condenser Corrected to 30 In. Barometer	Vacuum of Pump Suction Corrected to 30 In. Barometer	Barometer	Hot Well	Circulating Water Inlet	Circulating Water Outlet	Air Suction	Air Discharge	Air in Bell	R.P.M. of Pump	Air discharged per Minute measured in Bell	Air discharged per Minute at Temperature of Air Discharge	I.H.P. Steam Cylinder	I.H.P. Air Cylinder	Mechanical Efficiency of Pump, Per Cent	Water Used to Cool Air Cylinder: Temperature Inlet, Deg. Fahr.	Temperature Outlet, Deg. Fahr.	Cubic Feet used per Minute
		.	Inches of Mercury			Temperatures, Deg. Fahr.							Cubic Feet							
3	2/14/11	6,500	28 49	28 61	30.09	54.7	35.7	48.8	63 0	144.7	94.3	70.0	12 94	17 15	26 92	14 80	57.1	....	46 3	...
5	2/14/11	8,200	28.43	28 61	30 07	55.0	33.0	49.8	68.0	141.7	93.3	61.4	8 59	11.08	22.85	10 36	45.7	....	52 6	....
5	2/14/11	10,400	28.16	28.40	30.04	63.0	33.0	54.2	81.2	139.4	93.1	60.4	5.82	7.40	21.52	10.24	47.6	....	53 7	....
5	2/18/11	6,266	28 50	28.60	29.92	53.0	33.6	47.9	62.8	138.2	96.5	67.2	12.65	15.65	22.51	11 94	53.0	38.56	45.0	...
5	2/18/11	8,133	28.46	28 60	29.92	57.8	33.4	51.1	73.4	136.2	96.0	66.4	6 86	8.50	21.80	9.35	42.9	38 00	45 6	2 21
5	2/18/11	10,132	28.11	28.34	29.92	68.0	33.0	54.2	84.9	137.0	95.5	65.4	5.75	7.12	20.08	10.85	58.9	38.00	46.0	2.19
3	2/18/11	10,000	28.08	28.32	29.90	68.3	33.3	54.7	85.2	144.8	97 3	74.0	5.93	7.83	23 08	12.30	53 3	37.20	43.0	3 91
2	2/18/11	10,000	27 95	28.27	29.90	69.0	34.0	56.0	86.0	144.5	96 3	72.5	5.89	7.78	23.89	11.75	49 2	38 30	49.8	....
2	2/18/11	10,000	27.90	28.23	29.90	69.5	34.5	56.0	87.7	147.3	96.0	72.0	5.27	7.07	23.32	10.58	45.3	40.00	67.8	0.49
*3	2/28/11	No load	....	29.30	30.20	....	....	....	....	99.3	98.6	75.6	1.31	....	25.32	13 99	55.3	37.70	43.0	3.14
4	3/14/11	6,075	....	29.00	30.39	....	....	....	55.0	114.0	83.5	77.0	8.28	....	....	....	....	....	....	....
6	3/14/11	9,252	....	28 99	30.35	....	....	....	57.0	111.2	88.2	75.5	6.94	....	....	....	....	....	....	....
4	3/14/11	11,613	....	28.93	30.31	....	....	....	69.8	118.9	85.5	75.5	6.33	....	....	....	....	....	....	....
*2	3/15/11	No load	....	29.10	29.98	....	....	....	....	85.7	96.5	76.5	0.63	....	....	....	....	....	....	....
	1/26/12	9,100	27.67	28.74	29.89	....	33	60	91.8	105.0	87.2	....	29.25	31.25	....	....	....	....	....	....
	1/26/12	5,970	28.15	28.65	30.03	....	33	51	91.0	100.5	88.0	....	29.60	30.95	....	....	....	....	....	....
6	4/24/11	3,022	...	28.05	30.25	....	....	....	59.1	184	95	81	39.5	....	....	....	....	....	....	....
4	4/24/11	5,204	....	28 00	30.18	....	....	....	60 6	198	98	80	38.5	....	....	....	....	....	....	....
6	4/20/11	8,258	....	28.10	29.78	....	....	....	59.0	164	93	85	36.8	....	....	....	....	....	....	....

*Valve in suction line closed.

In a number of cases these readings showed excessive leakage in the condenser shell, which was remedied before the final readings were taken. A second apparatus has been provided for Waterside No. 1, and both stations at the present time are so arranged that in a few hours the air leakage of all the air pumps, as well as the condensers, may be tested. This is a great help in operating and serves a useful purpose in enabling attention to be given where there was no indication formerly of leakage.

A great many air tests have been made on all of the units in the two stations. Usually readings were taken during the time necessary to fill the bell (from one to 20 minutes) of the air temperature in the bell, the air suction temperature, air discharge temperature, vacuum at the top of the condenser, vacuum in the air suction line to the pump, hot-well temperature, circulating water inlet and outlet temperature, amount of cylinder cooling water with its inlet and outlet temperatures, revolutions per minute of the pump, power delivered by the prime mover and sometimes indicator cards on both air and steam cylinders. Table I. shows a collection of some of the more interesting of these tests.

In the experimental apparatus used to obtain the data for the paper on "The Transmission of Heat," it was impossible to detect any difference of temperature due to the segregation of air in the various parts of the single tube condenser. On the large condensers on which these air tests were made such a difference of pressure and temperature does exist, the differences of pressure being quite strongly marked. The curves for a number of these condensers, showing the increase in drop with the increase in amount of steam consumption, are illustrated in Fig. 3. A number of experiments were made to find if this drop was continuous through the tube surface or whether there were restrictions concentrating the drop in one or more places, and a number of experiments were made to reduce the amount of drop by taking out tubes, thus opening channels into the body of the tube surface. The results here were apparently negative.

To ascertain the effect of known quantities of air on the vacuum suitable orifices of various sizes were installed at the top of the condenser, so that the introduced air might mix with the incoming steam. These orifices were the ordinary circular orifices through thin plates and the amounts of air entering the condenser were checked up by the air delivered into the air bell from the air pump. These results are shown in Fig. 4. The tests in each case were run at constant load, which was considerably below the capacity of the condenser. Four sets of tests were run to determine the effect of load on

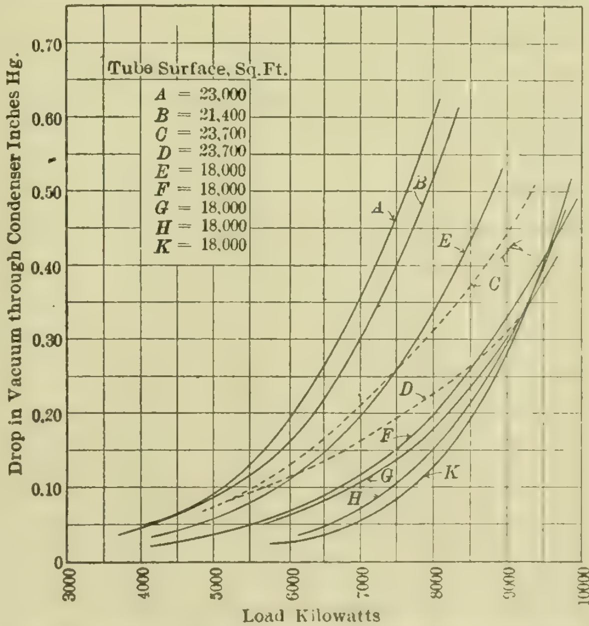


FIG. 3.—CURVES SHOWING RELATION BETWEEN LOAD AND DROP THROUGH CONDENSER

air leakage, two on machines which were in bad condition, and two on comparatively tight machines. The results are shown in Fig. 5. It should be noted that in every case the air leakage is less at the higher loads.

In the paper on "The Transmission of Heat" it was

inferred from Smith's curves that the heat transfer varied as the fifth power of the ratio $\frac{p_s}{p_t}$. Since that time many tests have been run from which sufficient data to calculate this relation were obtained, and the results are shown in Fig. 6. None of the tests approach the capacity of the tube surface, but the results are consistent.

Conclusions. — Where open heaters are used, very little air is carried to the prime mover with the steam. The volume of

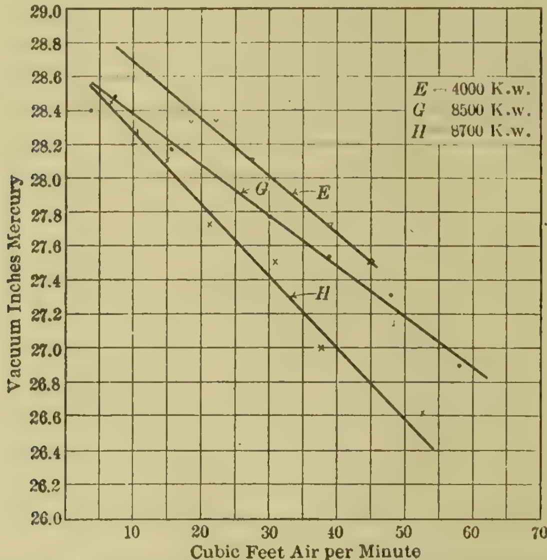


FIG. 4. CURVES SHOWING EFFECT OF AIR LEAKAGE AT CONSTANT LOAD.

this air at atmospheric pressure and temperature will probably not exceed 1 per cent. of the volume of the feed-water. As the whole system is under pressure from the pump nearly to the final stage of the turbine, no air leakage can take place up to that point.

The air discharged by the dry air pump at atmospheric pressure and temperature from units between 5,000 kw. and 20,000 kw. in size varies from 1 cub. ft. per minute when the

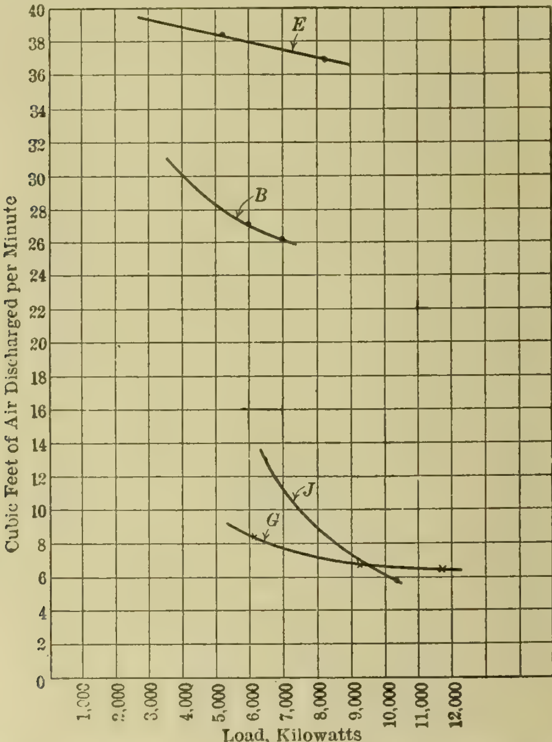


FIG. 5. CURVES SHOWING EFFECT OF LOAD UPON AIR LEAKAGE.

units are in the best condition, to 15 cub. ft. or 20 cub. ft. where ordinary leakage is present, and to 30 cub. ft. or perhaps 40 cub. ft. or 50 cub. ft. where the units are in very bad condition. Most of this leakage comes into the condenser and exhaust passages through minute leaks in the cast-iron shells, gaskets, and expansion joints. It is exceedingly difficult to detect these leaks with a candle flame, but most of them may be detected by filling the condenser with warm water under a slight head. That portion of the leakage occurring in the dry air pump and piping may be detected by the shut-off test on the pump. The volume of this leakage is larger than generally supposed and is much larger when the pump is warm.

The drop in vacuum through condensers of standard design is larger than it should be and a design which freely admits the steam to the tube surface should give better results. The opening of channels into the surface will not always improve conditions. The results indicate that wide shallow condensers should give better results, although in at least two instances deep narrow condensers gave good results. The falling-off of vacuum with increased air leakage is considerable and the work necessary to maintain tight condensers more than pays for itself.

Air leakage decreases with an increase of load. This fact in some measure corrects the decrease of vacuum at the increased loads. The exponent of the ratio $\frac{p_s}{p'}$ on page 1,161 of Volume 32 of the Transactions of the Society may be changed

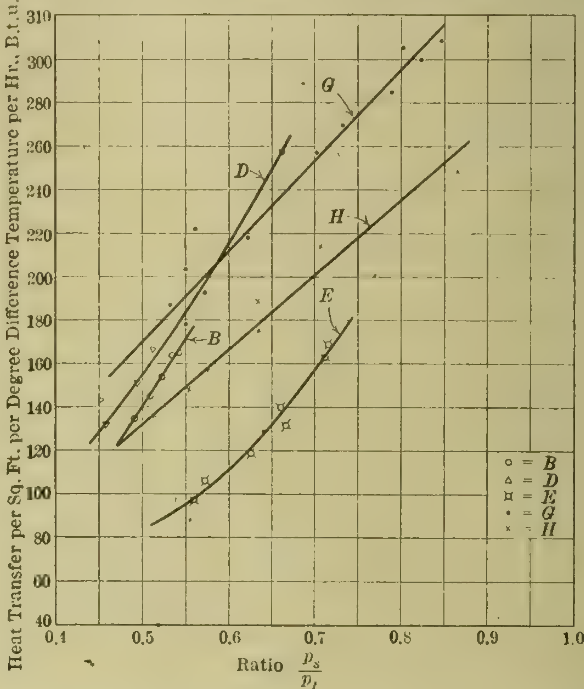


FIG. 6.—CURVES SHOWING RELATION BETWEEN RATIO $\frac{p_s}{p}$ AND HEAT TRANSFER.

from 5 to 2, pending further experiments to establish a better value.

During these experiments, in which four different kinds of dry air pumps were investigated, it became evident that the volumetric efficiency of a pump working between ¼lb. and 15lbs. absolute is very poor indeed. The difficulties of keeping valves, pistons, glands, and packing tight against such a tenuous fluid as air at vacuum pressures are of much greater moment than is usually believed. It is hoped that some of the types of kinetic air pumps now being placed on the market will reduce these difficulties to a practical amount.

Considerable difficulty was experienced in securing vacuum temperatures during these experiments and most of the work has been repeated a number of times where such temperatures are essential. It has been impossible up to the present time to secure readings which were entirely consistent, and the work along this line will be carried on until the cause of the discrepancy is ascertained and correct figures obtained. The author wishes to acknowledge the efficient aid rendered him in conducting these experiments by his assistants, Messrs. E. B. Rickets, J. H. Lawrence, and J. S. Kerins, and by P. E. Reynolds, engineer of tests.

Commercial Developments in South Wales.—Steps are being taken for the erection of tinplate works on Aberavon Moors, while 25 acres of land have been secured adjoining Port Talbot Docks for the construction of blast furnaces, sheet mills, by-product plant, and coke ovens.

PEAT FUEL FOR GAS PRODUCERS.

The results of a series of experiments conducted during 1910 and 1911 at the Fuel Testing Station, Ottawa, Canada, with a gas-producer plant, designed for use with peat fuel, are given in a report by Mr. B. F. Haanel, B.Sc., the Chief of the Fuel Testing Division, recently issued by the department of mines at Ottawa. The tests are divided into two parts: (I.) Those carried out with the gas-producer as originally constructed, which showed a good fuel economy, but left something to be desired as regards the cleanliness of the gas delivered to the engine. The deposition of tar in the gas main, and on the valves, cylinder, and piston of the engine, necessitated the cleaning of the parts affected. At the close of the run it was generally found necessary to remove the valves for cleaning, and to wash the cylinder and piston from time to time during the running of the engine. While the continuity of the running of the engine was at no time endangered by the presence of tar, the operation of cleaning occupied more of the engineer's time than was considered desirable. In order to obviate this trouble the producer was reconstructed.

Part II. deals with the tests carried out with the producer after reconstruction. It was found in the first of this series of tests that tar still reached the engine—in spite of the change in construction; and although a manifest improvement was discerned, it was found necessary from time to time to wash the cylinder and piston as in the previous series of tests. Further tests were conducted in order to observe the effect which changes in the distribution of the air admitted to the upper and lower combustion zones would have upon the production of tar. The results of these tests led, on the one hand, to the abandonment of the idea of totally destroying all the tarry matter within the producer itself, and on the other hand, to the necessity of separating the tar from the gas in the cleaning system. A solution of the problem was found by placing a gauze cone in the top chamber of the coke scrubber. After the inclusion of this cone in the cleaning system no further trouble with tar was experienced, and the operation of the plant was then found to be entirely satisfactory.

A summary of the results of the investigation are as follows: The peat producer-gas power plant, as now constructed, may be pronounced thoroughly reliable. Its operation may be carried on continuously for a week or more without having to shut down for the purpose of cleaning the valves of the engine. The engine has been operated for a period of 150 hours without removing either the admission or mixing valves for cleaning. It should not be found necessary, in commercial practice, to remove the piston for the purpose of cleaning more than once in six months. The operation of the producer is uniform, and the gas delivered to the engine varies only slightly during a ten-hours run. The removal of ashes and the cleaning of the fires can be done without interfering with the operation of the engine, due to a change in the quality of the gas. The plant can safely be left in the hands of an intelligent labourer after he has received, for a week or so, instructions in the handling of the plant from a competent engineer. The services of only one man are required to run this plant when it is operated on day-shift work only.

It is recommended that the gas pipes leading from the producer to the cleaning system and the tar filter be cleaned once a week, if possible, when the plant is run ten hours a day during the working days of the year. If this is done, very little will be required to keep the plant in good condition. The admission and mixing valves of the engine will not require cleaning for two weeks or more.

The consumption of fuel per b.h.p. hour, including stand-by losses, is for full load, 1·7lbs. of dry peat, or 2·3lbs. of peat containing 25 per cent. moisture; for ¾ load, the fuel consumption, including stand-by losses, is 2·1lbs. of dry peat, or 2·8lbs. of peat containing 25 per cent. moisture. In estimating fuel costs, the assumption is made that peat with a moisture content of 25 per cent. can be delivered to the producer for 8s. per ton. As the fuel burned in the producer does not require to be of the best quality, the fuel cost may be considerably reduced, since the broken peat bricks and considerable fines—which always occur in the manufacture of peat and otherwise represent a loss—can be efficiently utilised in the producer. Assuming, however, that peat can be delivered to the plant for 8s. per ton, and that the plant is run with a power factor of 75 per cent. for 3,000 hours, the fuel costs would be 42s. per b.h.p.-year, including stand-by losses. The first cost of a plant of this type depends on circumstances. Local conditions, capacity of plant, &c., change the first cost so considerably that any figures quoted might prove misleading. The net cost of developing power is considerably reduced by the sale of sulphate of ammonia and tar, which are recovered as by-products. This recovery, however, is attempted only in plants of larger size than the one described in this report.

BOOK REVIEWS.

A Primer of the Internal-combustion Engine, by H. E. Wimperis, M.A., Assoc.M.Inst.C.E., &c. London: Constable & Co. 7½in. by 5in.; 143 pp.; 2s. 6d. net.

The leading features of this book are its cheapness, the excellent way in which the main outlines and principles of the internal-combustion engine are presented, combined with the excellent series of examples interspersed in the various chapters in order that the reader's knowledge of the text may be tested. It is essentially a text book for class work, and as such we have every pleasure in recommending it both to teachers and students.

* * *

Vapours for Heat Engines, by W. D. Ennis, Mem.Am.Soc.M.E. London: Constable & Co. 8¼in. by 5¾in.: 78 pp.: 6s. net.

The contents of this book consist of a general discussion of the use of fluids other than steam for power generation, as well as the desirable vacuum limits in steam engines; also methods for computing the efficiencies of vapour cycles and a temperature entropy diagram for various vapours. The matter is little more than what is usually given in the introductory chapters of most text books on thermodynamics, and, having regard to these limitations, the book does not appeal to us as presenting anything either cheap or new.

* * *

The Gas Turbine, Theory, Construction, and Records of Results from Two Actual Machines, by Hans Holzwarth. Translated by A. P. Chalkley, B.Sc., A.M.Inst.C.E. London: Chas. Griffin & Sons. 9in. by 6½in.; 140 pp.; 7s. 6d. net.

Although little has so far been done with gas turbines in actual practice, it is a field which presents many features of interest to students of thermodynamics, and the problems connected with them, so far as we are aware, have not been worked out in anything like the detailed manner as in the two cases dealt with by the author, and hence, in presenting his work to English engineers, the translator has rendered them a service. The mathematics of the subject are necessarily difficult and the circle of readers on this account will be somewhat restricted, although we are equally certain that to those who are interested it will be of value.

BOOKS RECEIVED.

The Protection of Trade Designs, by Robert M. Neilson, M.Inst.M.E. Glasgow: Fraser, Asher, & Co., Ltd. Price 6d. net.

Fortieth Anniversary of "The Electrical Review."—Congratulations to our contemporary, "The Electrical Review," on its fortieth anniversary. We can recall in the late 'seventies, when the science of electricity was in its infancy, its first appearance in the shape of a modest little pamphlet issued at monthly intervals and comprising only 18 pages of editorial matter. That the new journal was appreciated and met a want will be evident from the fact that after a lapse of only six months it was converted into a bi-weekly, and a few years later into a weekly, while at the present time it comprises no less than 44 pages of literary matter. The journal has grown on its merits, and we can bear testimony to its fair and independent attitude on all questions coming within its field. We wish our contemporary the continued success it deserves.

THEORY AND EXPERIMENT IN THE FLOW OF STEAM THROUGH NOZZLES.*

BY PROF. J. B. HENDERSON, D.SC., ROYAL NAVAL COLLEGE, GREENWICH.

WHEN the Council of the Institution honoured the author by asking him to prepare a summary of the experimental work which had been done on the flow of steam through nozzles, in order to determine the lines on which further experimental investigation should proceed, he gladly complied with the request and hoped at an early date to complete the task. The scope of the investigation, however, was much wider than he anticipated. A careful study of the considerable amount of literature bearing on the subject made him realise that it

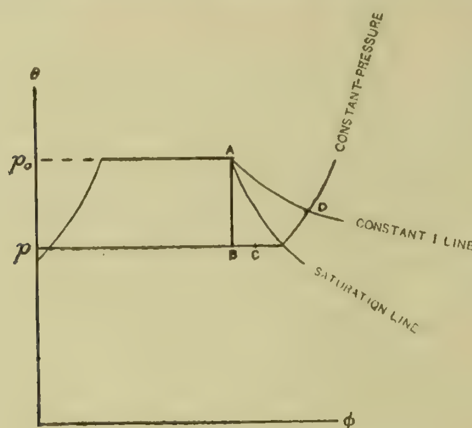


FIG. 1.—θ φ DIAGRAM FOR STEAM.

was hopeless to attempt to correlate the various experimental results which have been published without first making further experiments, and, as is shown below, some data which are of great importance in the author's opinion for a thorough knowledge of the subject are still altogether lacking.

THEORY.

The ordinary steam nozzle has a rounded mouth or entry, the shape of this curve of entry being chosen apparently at random. It has a throat or position of minimum diameter, and then expands generally in conical form to the exit orifice. The diameter at the throat and the initial pressure determine the mass flow, and the pressure at the throat is roughly half the initial pressure. The conical portion allows the steam to expand from the throat pressure to the pressure at the outlet orifice with corresponding gain of velocity.

The general theory assumes: (1) that the gas expands reversibly and adiabatically in the nozzle; (2) that the gas is moving parallel to the axis at the throat section; (3) that the pressure at all points in the throat section is the same; (4) that there is no friction anywhere in the nozzle; and (5) that there is no heat interchange between the nozzle and gas. Condition No. 1 really includes both 4 and 5, but it is more convenient to discuss the last two separately. If the suffix $_0$ refers to the initial state and the suffix $_1$ to the state at the throat section, the velocity at the throat is given by:—

$$\frac{u_1^2}{2} = \frac{n}{n-1}\left\{p_0v_0 - p_1v_1\right\} = \frac{n}{n-1}\,p_0v_0\left\{1 - \left(\frac{p_1}{p_0}\right)^{\frac{n-1}{n}}\right\}$$

where n is the index of v in the reversible adiabatic equation

$$pv^n = \text{constant}.$$

In order that the mass flow may be a maximum $p_1/p_0 = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}$ whence $u_1^2 = \frac{2n}{n+1}\,p_0v_0$, or in terms of p_1v_1, $u_1^2 = np_1v_1$.

But the velocity of sound in a gas is $\sqrt{npv}$; hence the velocity of the gas at the throat is the velocity of sound in the gas at the pressure and density prevailing at the throat. The maximum flow is given by:—

$$F = \frac{a_1u_1}{v_1} = a_1\sqrt{\frac{2n}{n+1}\frac{p_0}{v_0}\left(\frac{2}{n+1}\right)^{\frac{2}{n-1}}} = a_1\sqrt{\frac{np_0}{v_0}\left(\frac{2}{n+1}\right)^{\frac{n+1}{n-1}}}$$

where a_1 is the sectional area at the throat. These are text-book equations and require no further comment. In the case of gases n is a constant, and in the case of superheated steam Prof. Callendar has shown that n is also a constant whose value is 1·3, but this only applies to the superheated region. In the saturated region the theoretical equation to the adiabatics is:—

$$\frac{qL}{\theta} + \log\theta = \frac{q_0L_0}{\theta_0} + \log\theta_0.$$

There is no theoretical equation known for these adiabatics in terms of p and v, but Rankine showed that a first approximation is given by $n = \frac{10}{9}$, and Zeuner showed that $n = 1{\cdot}035 + 0{\cdot}1q$ gives a closer approximation, q being the initial dryness. Mr. Frank Foster in "The Engineer," April 10th, 1903, gave a table of values of n as a function of both the initial pressure and initial dryness.

To analyse the variations of the constant n, the author plotted the logarithmic homologues of the reversible adiabatics of wet steam for $\phi = 1{\cdot}5$, 1·6, 1·7, and 1·8, which covers most of the practical steam chart, and found that lines having the slope $\frac{10}{9}$ represented the curves fairly well, but the curves are very apparently not straight lines. In order to examine the deviation from the straight-line form with satisfactory accuracy, tables of the remainder $r = \log p + \frac{10}{9}\log v - c$ were formed, in which c is the constant in the straight-line equation. The values of r were then plotted on a base of $\log v$, and the resulting curves were found to be approximately parabolic in form. From the equations to these parabolas the equations to the adiabatics were deduced. They are of the form:—

$$\log p + \frac{10}{9}\log v = \frac{(\log v - \alpha)^2}{m} + \beta$$

in which α, β, and m are constants.

Since in practice only the initial and final states are of importance and an equation of the form $p_1v_1^n = p_2v_2^n$ would be useful when no steam chart is available, even if n were a function of both p_1 and p_2, the above equation has been transformed, and combined with the equations to the parabolas it gives:—

$$n = 1{\cdot}011 + 0{\cdot}073\,\phi + \log_{10} p_1p_2\,(0{\cdot}0175\,\phi - 0{\cdot}0165)$$

if p_1 and p_2 are in kilograms per square centimetre, or:—

$$n = 1{\cdot}011 + 0{\cdot}073\,\phi\ (\log_{10} p_1p_2 - \log 28{\cdot}44)\,(0{\cdot}0175\,\phi - 0{\cdot}0165)$$

if p_1 and p_2 are in pounds per square inch. The index is thus

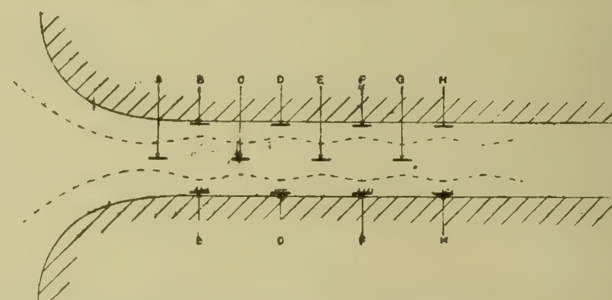


FIG. 2.—DISTRIBUTION OF CONDENSATIONS AND RAREFACTIONS IN A PARALLEL NOZZLE. The dotted lines show also the average direction of flow.

a function of p_1, p_2, and ϕ, and it is questionable whether such a complicated formula will have any practical importance. It serves the purpose, however, of showing the errors which are introduced by taking n as a function of the initial conditions alone.

DIFFERENCES BETWEEN THE PRACTICAL AND THE IDEAL NOZZLES.

Efficiency of a Nozzle.—An ideal nozzle would expand the steam or gas reversibly and adiabatically, so that if A, Fig. 1, were the initial state point on the entropy-temperature diagram, the state point after expansion would be B. Any irreversibility in the flow due to friction would cause the state point after expansion to move to the right along the constant-pressure line p, to some point, say, C. A nozzle which would allow the gas to pass molecule by molecule from pressure p_0 to pressure p without gain of kinetic energy would have zero efficiency for the purpose for which a nozzle is designed. Lord Kelvin's porous plug constitutes such a nozzle, and the state-

* Paper presented before the Institution of Mechanical Engineers, October 25th, 1912.

point after passing through the plug would be D, the point of intersection of the constant-pressure line p with the "constant heat" line through A. The state point in practical nozzles will lie between B and D, and if no heat is lost by conduction a natural scale of efficiency of the nozzle is obtained, if we define the efficiency either by

$$\eta = \frac{\phi_C - \phi_D}{\phi_B - \phi_D} \text{ or by } \eta = \frac{I_C - I_D}{I_B - I_D}$$

where I is Mollier's variable $E + pv = I$, and in steam is practically the same as the total heat. These two definitions are identical if the constant-pressure line is also a line of constant temperature, as in the saturated steam region.

The initial and final states of the steam would then serve to determine the efficiency of the nozzle. Unfortunately, the heat conduction phenomena make such a definition impossible.

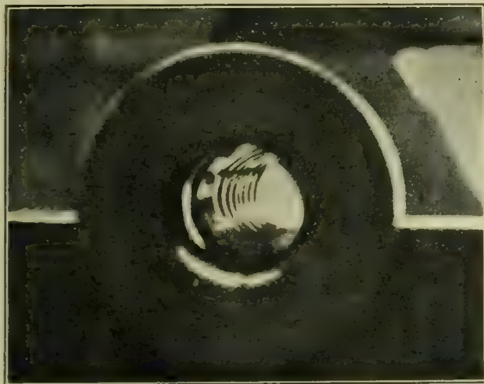


FIG. 3.
NOZZLE OF 5 MM. BORE, ERODED BY CORDITE GASES TO ABOUT 20 MM. BORE.

The steam loses heat to the nozzle near the inlet end, the nozzle loses heat to the surroundings and may also return some heat to the steam before it leaves the outlet end of the nozzle. Every one of these heat transferences constitutes an irreversible change and therefore a loss of efficiency, and these changes cannot be represented on the $\theta\phi$ diagram of the steam alone. In fact the loss of heat to the nozzle will bring the state point C nearer to B, and, if the above definition were adopted, one irreversibility would apparently compensate for another irreversibility, instead of which both must diminish the efficiency. The efficiency of a nozzle or turbine therefore cannot be obtained from the initial and final conditions of the steam unless it be proved that no heat conduction takes place. Hence resort must be made to experiment to determine the efficiency of a nozzle just as with any other heat engine, the efficiency of the nozzle being the ratio of the *actual* kinetic energy of the steam leaving the nozzle to the *ideal* kinetic energy.

Maximum Mass Flow Depends on the Shape of the Curve of Entry to the Nozzle.—The maximum mass flow calculated by the general theory is based on certain assumptions, and if these assumptions are not approximately satisfied by the practical conditions, no surprise need be felt if the actual flow deviates considerably from the theoretical, even if it exceeds the theoretical. It is assumed that the pressure is uniform across the throat section, and also that the flow is in parallel stream lines at the throat section. If gas were incompressible, it might be possible to get it to flow into a bell-mouthed orifice in stream lines so as to satisfy these assumptions, but since gas is compressible, its inertia is bound to produce a condensation at the axis of the nozzle near the throat, say, at A, Fig. 2, and a corresponding rarefaction on the walls at the A section, with corresponding inverse variations of velocity across the section. This condensation at A will give rise to transverse oscillations or waves in the moving column, producing stationary condensations on the walls at B, D, F, &c., and on the axis at C, E, G, &c. The stream lines also, if any exist, will not be parallel, but sinuous, as shown in the drawing.

The magnitude of these condensations and rarefactions will depend on the shape of the curve of entry to the nozzle, and the shorter this curve is the greater they will be. When this curve has zero length and the nozzle has a sharp corner at the inlet end, it is a well-known fact that the maximum flow is considerably altered, and if the nozzle is simply a hole in a thin plate, there is no maximum flow, but the flow increases with reduction of back pressure asymptotically towards a limit. It is surprising that so little attention has been paid to the curve of entry, since it apparently ought to affect not only the mass flow, but also the irreversible phenomena throughout the nozzle.

An unequal distribution of pressure over a cross-section of the nozzle involves an inverse unequal distribution of velocity across the section, and since the viscosity of the gas introduces eddies, the friction losses are likely to be materially affected by these transverse waves. Thus these waves, although in themselves not irreversible, ought materially to affect the irreversible phenomena in the nozzle. It is unfortunate that the theoretical hydrodynamical problem of the flow of a gas through a frictionless nozzle of given form cannot be solved. If this were possible even for a single particular form of the curve of entry, we should be able to say whether the mass flow might exceed the maximum obtained on the assumption of uniform pressure over the throat section.

In practice the curve of entry is made very short, hence the inertia oscillations are probably great. The position of the first condensation on the axis (A in Fig. 2) will depend on the shape of the curve of entry and the mass flow might be expected to vary accordingly.

It is of interest to examine theoretically the distance apart of the condensations along the axis of a parallel nozzle. The theoretical velocity in the nozzle, if the stream lines are parallel, is equal to the velocity of sound in the gas at the same pressure and density as prevail at the throat, and in practice the velocity will approximate roughly to this value. Consequently, while a particle of gas moves from A to C in Fig. 2, a sound wave has moved radially outwards to the nozzle wall and back again to the axis, that is, the wave has moved through twice the radius while the gas has moved through the distance AC; and, since the velocity of the gas is approximately that of the sound wave, the distance AC is approximately twice the radius of the nozzle.

Experimental Evidence of Transverse Waves in Nozzles.—All the published records of the pressure distribution along the axis of a nozzle give the pressure at a number of points, and through these points the experimenters have drawn smooth curves; hence these curves cannot be used as evidence for or against the presence of transverse waves in the nozzle, since it is equally justifiable to draw a sinuous curve through the points. Inertia oscillations have been noticed, however, in the expanding portion of the nozzle and also outside the nozzle in the steam jet, whenever a sudden jump of pressure takes place. Curves showing these oscillations are to be found in



FIG. 4.
PLASTER CAST OF THE TWO HALVES OF A NOZZLE ERODED BY CORDITE GASES.

several works on the steam turbine, for example, Stodola or Jude. In a paper by Mr. T. B. Morley describing experiments on the De Laval turbine in the Engineering Laboratories of Glasgow University, publishing in "Engineering," December 29th, 1905, some curves are given of the distribution of pressure along the axis of the nozzle, which seem to show signs of sinuosity even near the throat, but they have been reduced to such a small size for publication that it is impossible to plot the theoretical curve beside them. The theoretical curve of pressure distribution is so steep near the throat that variations of several per cent. in the pressures

only produce a slight shearing of the steep portion of the curve, hence the importance of having the theoretical curve plotted beside the experimental for purposes of comparison.

The most direct evidence is to be found in some experiments by Sir Andrew Noble made to compare the erosion of different steels by the gases resulting from the explosion of cordite and other high explosives. The cordite was exploded in a chamber from which the gases escaped through a short circular cylindrical nozzle. The inside surface of each nozzle was found to be eroded in a series of waves. The author is indebted to Sir Andrew for the loan of these nozzles in order to photograph them, and for his kind permission to publish two of these photographs, which are shown in Figs. 3 and 4. Fig. 3 shows a view looking through one of the nozzles in the direction of the flow, and Fig. 4 shows a section of a plaster-cast of one of the eroded nozzles. The regular wavy surface is not so clear in Fig. 4 as in Fig. 3. The original diameter of both nozzles was about quarter that of the eroded nozzles, and the bore was smooth and circular with sharp corners at entry and exit, the bore being about 5 mm. Since we have seen that the distance between the condensations is equal to the diameter of the nozzle, it is evident that, as the diameter increases, the erosion waves produced by one explosion will be partly obliterated by the erosion due to succeeding explosions; hence the irregularity of the surface in Fig. 4.

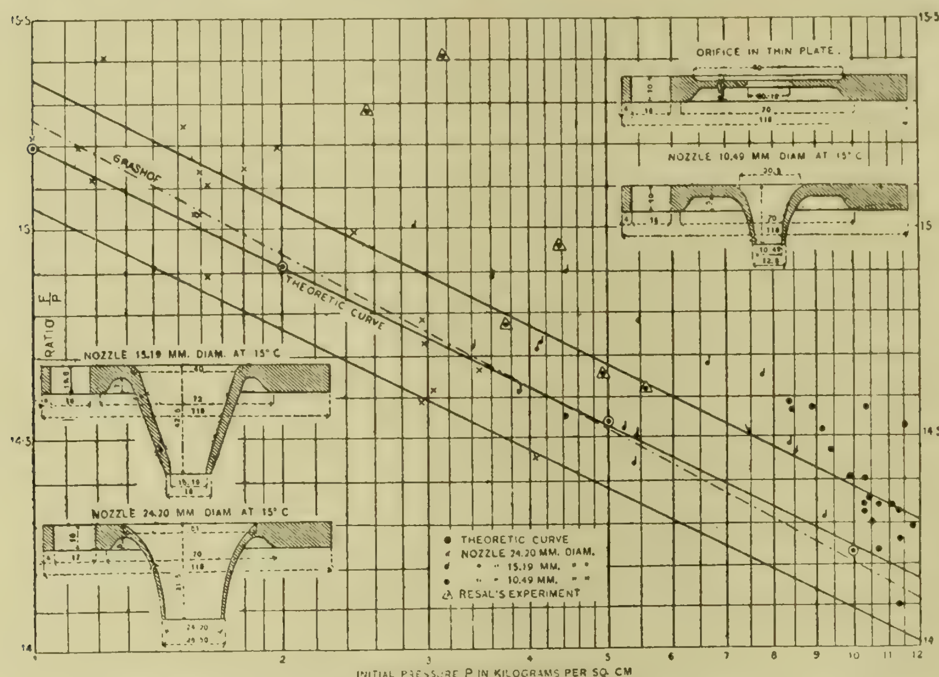


FIG. 5.—RATEAU'S EXPERIMENTS ON THE FLOW OF STEAM WITH THE BACK PRESSURE LESS THAN 0·58 SUPPLY PRESSURE. SHOWING THAT THE EXPERIMENTAL FLOWS EXCEED THE THEORETICAL.

It would be very interesting to see one of these nozzles after a single explosion of a small charge of cordite, and still more interesting if a thin circular rod could be screwed into the back of the explosion vessel coaxial with the nozzle and long enough to project through the nozzle. The wavy surface on the rod could then be compared with that on the walls of the nozzle and would clearly demonstrate, by the relative positions of the two sets of waves, whether the oscillations are transverse or not. It is difficult to imagine any other cause to account for the wavy surface than these oscillations across the nozzle, which must be introduced by the contraction of the stream at entry. They must produce variation of pressure and also of temperature, and where the temperature is highest there the erosion must be greatest.

Some experiments were made three years ago in the Engineering Laboratory of the Royal Naval College, Greenwich, to try to reproduce these waves of erosion in steam nozzles lined with fusible metal, but it was found difficult to stop the flow at the critical moment, and as a rule the metal was either untouched or almost completely melted. The heat conductivity was evidently too great and the differences of temperature too small for success, without some special arrangement for observing the erosion as it occurred.

Let us now examine the experimental evidence to see if the actual mass flow does in some cases exceed the theoretical, calculated on the assumption of uniform pressure at the throat section. Prof. Rateau has carried out a beautiful set of experiments on the flow through four nozzles.* The measurements were all made with great accuracy. The four nozzles are illustrated and the results are plotted in Fig. 5. The points refer only to the experiments in which the back pressure was less than 0·58 of the initial pressure, and since in such a case the theoretical equation for the mass flow F in terms of initial pressure p_0 is

$$\frac{F}{p_0} = a - b \log p_0,$$

the ordinates are F/p_0 and abscissæ $\log p_0$, and the theoretical discharge straight line is drawn in the diagram. It will be noted that almost all the experimental points lie above the theoretical line, indicating a flow greater than the theoretical. Thus for nozzle 1 the mean departure is 1·17 per cent., for nozzle 2 it is 0·69 per cent., and for nozzle 3 it is 0·25 per cent.

No surprise would be felt if the experimental flows were 1, 2, or more per cent. below the theoretical because of the friction in the bell-mouthed entrance, but any excess requires explanation. Prof. Rateau tries to explain it away by altering the assumed value of Joule's equivalent, by assuming that changes took place in the zero of his thermometers, &c.; but the maximum changes he can allow in these factors only increase the theoretical flow about 1 per cent. Rateau is not the only experimenter, however, whose results show a flow greater than the theoretical. Hirn, in his experiments on the flow of air, obtained similar excesses in the case of back pressures being less than $0·5p_0$. The evidence seems, therefore to throw suspicion on the ideal nozzle.

Further evidence should be obtainable from experiments in which the back pressure is greater than $0·58p$, because the inertia effects in the radial direction should increase with the velocity, and therefore with the difference of pressure at the ends of the nozzle. Rateau's results for back pressures greater than $0·58p_0$ are shown in Fig. 6, in which the ratio of the flow to the maximum flow is plotted in terms of the ratio of the back pressure to the initial pressure. It will be noted that for the pressure ratio 0·95 the experimental curve is 6 per cent. below the theoretical, at 0·8 it is 3·3 per cent. below, at 0·7 it is 2·6 per cent. below, and at 0·58 we have seen that the experimental curve is the higher. Yet the velocity and inertia effects have been steadily increasing, and it is natural to expect that the deviation should also be increasing. The obvious explanation is that the theoretical curve is at fault.

Dr. Walter Rosenhain, in one set of his experiments† on the flow through nozzles, used a nozzle that was made in two parts separable at the throat. The mass flow with the conical diverging part fixed was found to exceed the mass flow without it. This strange result cannot be explained on the assumption of uniform pressure at the throat section. The theoretical mass flow for that particular nozzle, as calculated on the general theory, is not given, but Prof. Rateau has shown that another of Dr. Rosenhain's nozzles passed 5 per cent. more steam than the general theory allows, which Prof. Rateau ascribes to the uncertainty in the initial wetness of the steam. It seems a large amount to be accounted for by that uncertainty.

Again Dr. Rosenhain found the flow through a hole in a thin plate to be only about 6 per cent. less than the flow through a properly-shaped nozzle having the same area at the throat as the hole, but Prof. Rateau has since shown that the flow through a flat-plate orifice depends upon the back pressure, Fig. 6, and may be as much as 25 per cent. less than the flow through the nozzle. In a flat-plate orifice the difference of pressure across the section of the nozzle must be a maximum, hence the divergence from the general theory should be a maximum.

* "Rateau on the Flow of Steam"; published by Constable, London.
† "Proceedings Inst.C.E.," 1900, Vol. CXL., p. 199.

It is quite possible that the coefficient of friction between the steam and the metal walls of the nozzle diminishes considerably at velocities approaching the velocity of sound, but even a zero coefficient will not account for the discrepancies between theory and experiment. Also, even if the friction on the walls were zero at these very high velocities, the inertia oscillations, by introducing a differential velocity across every section, would still cause friction losses, the relative velocity of the gas giving rise to eddies just as it would at low velocities.

Suggestions for Further Experiments.

It is highly desirable that some further experiments should be carried out on the influence of the curve of entry on the flow from nozzles of equal diameters. Comparative experiments would be best, the two nozzles being connected each to one of two similar jet condensers, fed by water flowing through equal orifices from the same tank. The comparison would then consist in reading a differential thermometer giving the difference of the temperatures in the condenser discharges. An interchange of steam or water nozzles in the two condensers would eliminate any inequalities in the flow of water. One nozzle could be kept of standard shape and the other varied according to some definite plan. Until further light is thrown on this point no comparison is possible between the results obtained by different experimenters, since some of these have simply calculated the mass flow from general theory. It is also desirable to determine whether the length of the parallel portion at the throat materially influences the mass flow.

The mass flow is most difficult to determine accurately, and it is unfortunate that experimenters have employed the direct measurement method which is difficult, instead of the comparative method which is easy. The comparative method might also be employed for comparing the efficiencies of nozzles by measuring the ratio of, or the difference between, the reactions of the nozzles fed from the same source.

For practical purposes it is not sufficient to determine the efficiency of a nozzle simply as a transformer of heat energy into kinetic energy, because the nozzle has to be utilised in connection with turbine blades, and unless the jet impinges on the blades exactly as it is intended to do, a further cause of inefficiency may arise. It is of importance to examine the jet, therefore, to see that it is parallel on leaving the nozzle when the supply pressure and the back pressure are those of design, otherwise part of the jet may not strike the blades at all, or the jet by contracting may not fill the blade space, thereby introducing unnecessary friction due to the unused portion of the blade length. Unless the pressure is uniform over the outlet orifice and equal to the back pressure the jet will not be parallel. Hence, if the nozzle is very short as in some multiple-stage turbines, the inertia oscillations cannot have died out in the short length, and the jet will not emerge as a parallel stream. It would be interesting to note the change in the shape of the emerging jet as the parallel outlet end portion of the nozzle is lengthened or shortened, thus altering the relative positions of the end section and the transverse waves. This may account for the difference which Mr. Rosenhain noticed between the shape of the jet issuing from his nozzles and the photographs of jets published by Parenty.*

In De Laval nozzles the long tapering expanding portion probably gives the inertia oscillations time to die out in the nozzle, and leave the emerging jet parallel, provided there is no sudden change of pressure at exit; but it does not follow that a curve of entry which is satisfactory in a long De Laval nozzle will be equally so in a non-expanding or a short expanding one, say, in a multiple-stage turbine.

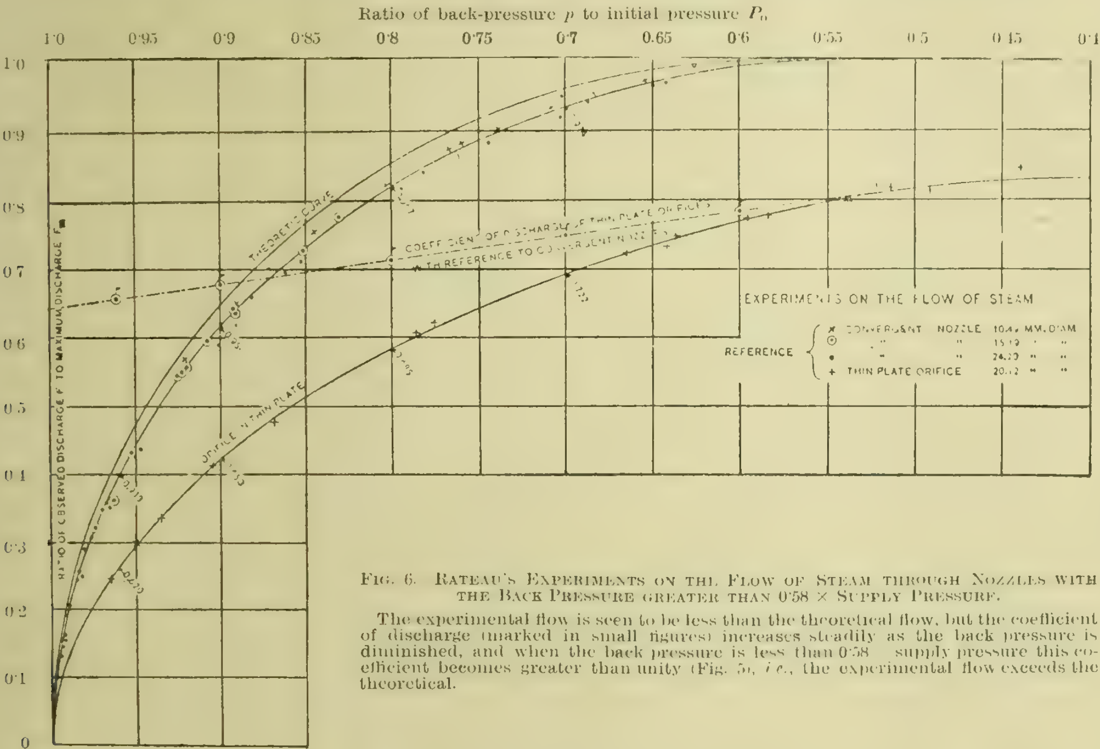


Fig. 6. Rateau's Experiments on the Flow of Steam through Nozzles with the Back Pressure greater than 0·58 × Supply Pressure.

The experimental flow is seen to be less than the theoretical flow, but the coefficient of discharge (marked in small figures) increases steadily as the back pressure is diminished, and when the back pressure is less than 0·58 × supply pressure this coefficient becomes greater than unity (Fig. 5), *i.e.*, the experimental flow exceeds the theoretical.

If the oscillations have died out before the exit orifice is reached, then one may speak of the pressure and state of the steam at the exit section, but unless the heat lost by conduction is known the theoretical equation cannot be applied. In order to get some idea of the magnitude of the heat-conduction effects in a nozzle of De Laval pattern, some experiments were made in the Engineering Laboratory of the Royal Naval College, Greenwich, by Eng.-Lieuts. H. H. Carter and H. T. Evans in session 1909-10.

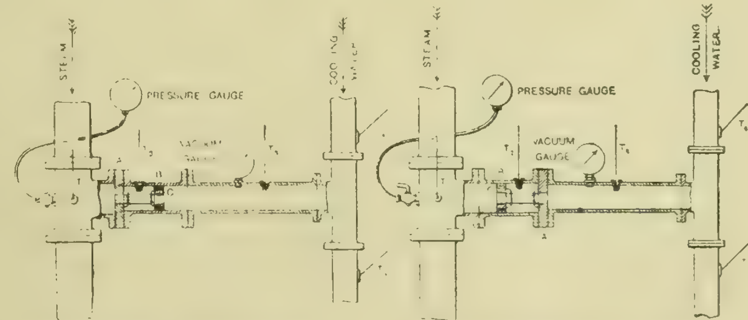


Fig. 7.—Nozzle Surrounded by Exhaust Steam. Fig. 8. Nozzle Surrounded by Live Steam.
Experiments on Heat Conduction through Nozzles.

The method employed was to compare the flow of heat carried into a jet condenser by the steam flowing through the nozzle when the nozzle was surrounded by steam at condenser temperature, with that when the nozzle was surrounded by steam at boiler temperature, thus to a certain extent reversing the heat-conduction effects. The method is not a very accurate one, since the heat conducted is a small fraction of the total heat carried by the steam into the condenser.

* "Annales de Chimie et de Physique 7," série viii., 1896, and xii., 1897.

Fig. 7 shows the arrangement of the apparatus with the nozzle surrounded by the exhaust steam, and Fig. 8 shows it with the nozzle surrounded by live steam. It will be seen that the nozzle is carried between a "blank flange" A and a perforated diaphragm C. In Fig. 8 the diaphragm is necessary to keep the stream lines at entry similar to those in the Fig. 7 arrangement, and in Fig. 7 the diaphragm helps to keep the steam which surrounds the nozzle more nearly saturated, since the steam on its way to the condenser is considerably superheated. (The reading of the thermometer T_2 was from 40° to 60° Fah. below that of thermometer T_3 in Fig. 7, and about 20° below that of thermometer T_1 in Fig. 8.) The results of the experiments are plotted in two curves in Fig. 9, in which the heat flow into the condenser is given as its equivalent in mass flow of steam. Since the mass flow of steam must have been, for the same initial pressure, the same in both cases, the difference between the two curves gives some idea of the magnitude of the heat-conduction effects. The nozzle was designed for an initial pressure of 200lbs. per square inch and a high vacuum, so that the only points of practical importance on the curves are those on the ordinate 200 which occurs just at the part of the curve where the experimental points are most irregular. The method of experiment is a rough one, but the results show that there is an appreciable heat-conduction effect well worth investigating in an accurate manner.

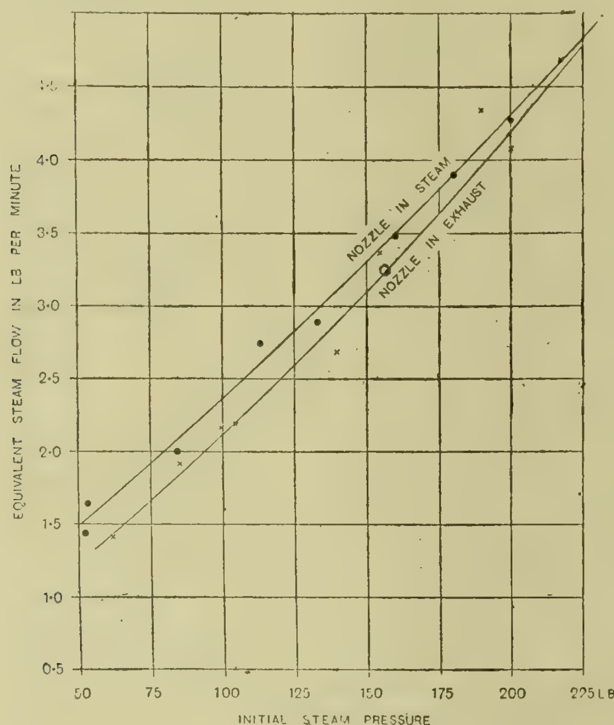


FIG. 9.—CURVES SHOWING EFFECT OF CONDUCTION OF HEAT THROUGH WALLS OF THE NOZZLE.

The conclusions arrived at in the paper may be summarised as follows:—

(1) The generally accepted theory of the flow of gases and vapours through nozzles is defective, in that it makes no allowance for the inertia and compressibility of these fluids, and the assumptions made in that theory do not seem to be very completely realised in practice.

(2) No complete theoretical treatment of the problem of the flow of a frictionless but compressible fluid is possible at present, but there is no reason prima facie for assuming that the maximum flow which such a solution would allow would not exceed the maximum as calculated by the general theory. This is the probable explanation of the experimental flow exceeding the theoretical in many cases.

(3) The erosion of nozzles which occurs when gases resulting from the explosion of cordite flow through them throws light on the influence of inertia and compressibility on the flow, the irregular wavy erosion being probably due to transverse oscillations in the gas.

(4) Experiments are described which show that the effect of heat conduction through the nozzle is by no means a negligible quantity when dealing with the flow of steam.

(5) Further experimental investigation is required on the following points: (*a*) The influence which the shape of the curve of entry exerts on the flow through short nozzles. (*b*) The influence of the transverse oscillations on the shape of the issuing jet. (*c*) The heat conduction through nozzles. (*d*) The efficiency of nozzles.

In conclusion, the author desires to express his thanks to Prof. Rateau for his permission to publish Figs. 5 and 6, and to Sir Andrew Noble for the loan of the nozzles which he used in his cordite experiments, and for his kind permission to publish the photographs on Plate I illustrating the erosion of these nozzles.

ENGINEERING EDUCATION.

IN his presidential address, delivered to the Liverpool Engineering Society, Prof. W. H. Watkinson said that greater value had been attached in this country to the art than to the science of engineering, with the result that the Germans were better fitted to develop those branches which were more dependent on scientific knowledge. The high-lift turbine pump was invented by Prof. Osborne Reynolds, but German and other continental engineers had developed it, while British manufacturers had to buy continental designs of the water turbine. The 2-stroke gas engine was invented by Dugald Clerk in 1880, but its development was left to Körting, of Hanover, and the application of this cycle to Diesel engines was being developed in Germany and other continental countries. All the large internal-combustion engines, whether gas or oil, built in this country were constructed to German or Belgian designs, for which British manufacturers had to pay. The application of Diesel engines to marine propulsion had been entirely developed on the Continent, the large steam turbine, although first rendered successful by Parsons, had been studied from the scientific point of view in Germany and Switzerland, and an enormous turbine plant for South Africa had been manufactured in Berlin. The application of superheaters to locomotives was almost entirely due to Germans.

He had, he said, during the last few years visited all the principal schools of engineering in Germany, the United States, and Canada. In this country the majority of engineers and mechanics had received their scientific training at evening classes, and although this system had produced some of the most capable men, owing to the development of engineering science it was no longer possible to obtain adequate training in this manner in the higher branches of the profession. When the Americans awakened to the need of better scientific training they went to Germany for their models for the schools, and although some progress had been made in this country in regard to recognising the new conditions, a large amount of leeway had to be made up. In the United States there were in 1908-9 approximately 17,700 engineering students in the principal schools, a number that was more than double what it had been six years previously, and in the technical high schools of Germany there were last session 10,998 students who were taking the regular diploma or degree courses in engineering, shipbuilding, and mining, or, with 5,000 not qualified to take such courses, a total of about 16,000 students. During the last session in the universities and technical high schools of England and Wales there were only 1,623 full-time engineering students, or, with Scotland, a little over 2,000. Abroad the employers co-operated with the schools in assisting students to obtain practical training, and in Berlin there was a special bureau for organising this training which had a list of 500 firms willing to take students into their works. Students in America managed to earn sufficient to maintain themselves while at the university, but English students rarely appeared to have this ability to help themselves. At present the principal difficulty with a considerable number of the students in this country was that on completion of their university training their private funds were exhausted and they could not afford either to pay a premium or to undergo two or three years' apprenticeship at the existing scale of wages. This difficulty would be solved by employers giving a more liberal scale of wages to college-trained apprentices.

Accidents on British Railways.—A Board of Trade report published a few days ago shows that during the second quarter of the current year 210 persons were killed and 1,818 injured by railway accidents in the United Kingdom.

INTERNATIONAL ENGINEERING AND MACHINERY EXHIBITION, OLYMPIA.—VII.

Mr. S. N. Brayshaw, of 2, Mulberry Street, Hulme, Manchester, exhibited several new types of his well-known furnaces, together with furnace accessories, temperature measuring instruments, small tools, and miscellaneous accessories. Several of these we have pleasure in illustrating and describing herewith.

Fig. 1 shows a furnace suitable for case-hardening, ordinary steel hardening, annealing, and for a variety of operations which admit of the flame entering the chamber that contains the work. For economy of gas and rapid heating this furnace, it is claimed, is unrivalled, but it cannot be used for work which requires a muffle to protect it from the flame or from the products of combustion. As will be noticed, it consists of a single chamber having a balanced sliding door, the latter being the same size as the chamber itself. A special quality of firebrick is used for lining the furnace, and the whole is enclosed in a strong steel frame, and provided with gas fittings, damper, and flue. The complete furnace is self-contained and stands on the floor, no table or special foundation being required. It is heated by a patent gas burner, by means of which an effectively reducing flame can be maintained without a wasteful excess of gas. The inlets are close to the sides of the chamber and discharge vertically downwards from the arched roof in such a way as to heat the chamber with great uniformity, and without a cold mouth. Coal gas or producer gas is used at ordinary pressures, or the burners can be arranged for high-pressure gas. Compressed air is also required at a pressure of one or two pounds per square inch. Large quadrant taps accurately regulate the gas and air, so that the temperature of the furnace is under perfect control. The commonest method of case hardening is, in general terms, to heat the pieces in boxes with bone chips or other suitable material for a sufficient length of time at a temperature of about 950° C.(1,742° Fah.), and then to quench out at once in cold water. The best case-hardening, however, is done in two or more separate processes, which vary according to circumstances, but, briefly, the first process consists of carburising only, that is, the articles are heated in boxes exactly as above, but are then allowed to cool slowly or are quenched in oil. The pieces so carburised are next heated to a temperature of about 760° C. (1,400° Fah.) and quenched in water, after which they may be tempered, or further treated in other ways. This furnace is specially adapted to the first of these processes, and is also suitable for the second heating. But a still further improvement is effected by using a Brayshaw patent salt bath furnace in the second process for heating the carburised pieces. The salt bath ensures absolute uniformity of heating, and the temperature is known with certainty, all the elements of chance being thus removed.

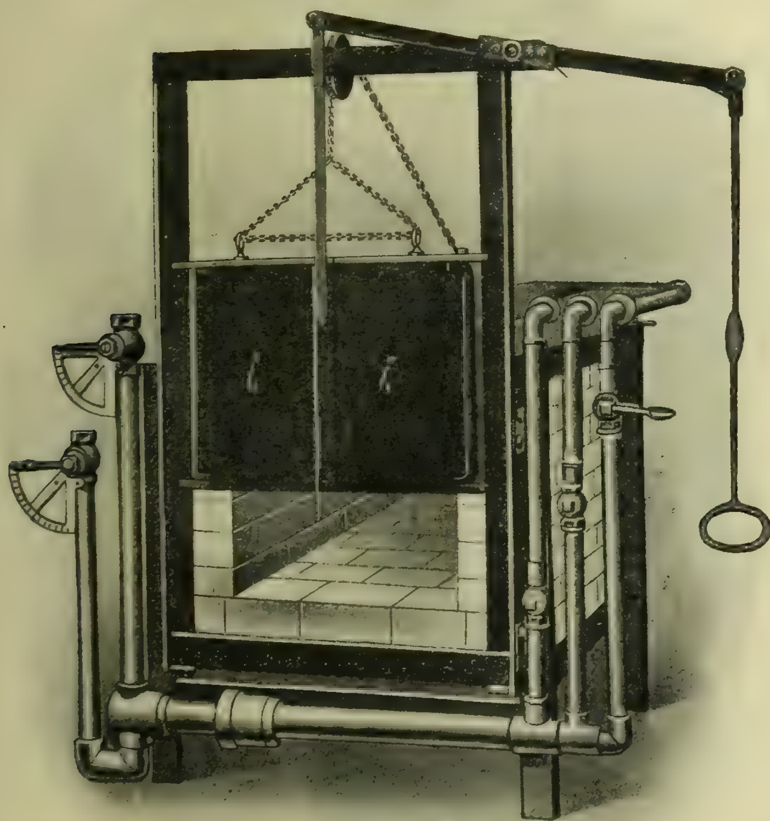


Fig. 1.—Case-hardening, Annealing, &c., Furnace, fitted with patent burner. Mr. S. N. Brayshaw, Manchester.

Another new furnace is shown in the illustration, Fig. 2. This has been designed for melting such metals as aluminium, brass, bronze, copper, iron, nickel, silver, gold, &c.; and like the one previously described, is fitted with the patent burner. The burner is, as previously mentioned, applicable to producer gas, and temperatures up to 1,300° C. (2,372° Fah.) can be obtained with it in this furnace with gas of 150 B.Th.U. The furnace is lined with special refractory material and surrounded by a great thickness of lagging to retain the heat and economise gas. A stock is kept, we are informed, of spare linings, and these being easily placed in position, save the time of rebricking, whilst they ensure the furnaces being correct.

Two illustrations (Figs. 3 and 4) which we give of a milling cutter guard, as made and exhibited by Mr. Brayshaw, are almost self-explanatory. These are readily attached to the machine, are adjustable in many ways, and, while complying with the Home Office regulations, afford the necessary protection without obstruction.

An ingenious lock-nut shown by the firm we illustrate in Fig. 5. This is made in all sizes from ¼in., Whitworth Standard, and will be found useful on all machinery subject to vibration. When the lever is drawn back and the stop point on its under side catches in the niche on top of nut, the teeth of the spindle are then clear of the thread on the bolt, and the nut will unscrew freely. When released, the lever springs back and the teeth of the spindle make a dead grip on the bolt. The nut can be screwed on the bolt either in the locked or unlocked position. In the locked position it is perfectly automatic, and can be screwed further on, but it cannot work back unless released. To remove the nut, it should be turned slightly forward before releasing.

Messrs. E. G. Wrigley & Co., Ltd., of Foundry Lane Works, Soho, Birmingham, exhibited a drilling machine in motion to show the performances of their well-known high-speed twist drills. A good assortment of small tools, including drills, milling cutters, and reamers, were also shown, together with samples of cut gearing.

Messrs. Hans Renold Ltd., of Progress Works, Manchester, exhibited numerous examples of steel driving chains and wheels, in the manufacture of which they have specialised and for which they are well known. Three main types were represented, viz., silent chains (the first patent for which was granted to Mr. Hans Renold in 1895) and wheels for same; roller chains; and block chains. These, however, will be familiar to most of our readers, from past descriptions of same, and so we do not purpose further describing them in the present article.

Messrs. James R. Kelly & Co., Ltd., of 3 and 5, Bridge End, Leeds Bridge, Leeds, exhibited several interesting and novel machine tools, chief of which we may mention were a Bryant multiple spindle chucking grinder; a De Fries "H.R." 36in. semi-automatic chucking lathe; and a 10in. centre Walthem single pulley drive, high-speed lathe, the special feature of the latter tool being a quick return to the saddle with a ratio of 8 to 1. The first-mentioned tool was fitted with three spindles, one for internal, one for external, and a third for

face grinding, and to all intents and purposes embodied the principle of turret lathe design as applied to a grinding machine.

The De Fries chucking lathe was an improvement on the usual chucking lathe in that the slides were covered, while the chucking lever was so placed that the operator could fix up the work very quickly indeed. There were also other special features we have not space to describe at length, but we should say that the combination of this tool with a Bryant grinder such as previously mentioned would be an ideal one for motor-car manufacturers, the automatic lathe roughing out, and the chucking grinder finishing the work.

Other tools shown were a De Fries full automatic screw-making lathe for making screws up to ½in. diam.; a Maffei high-speed vertical drilling machine; a Maffei rapid cutting-off machine capable of cutting off an 8in. bar in five minutes; and a single pulley drive shaping machine, of 5in. stroke, driven by single pulley, with Norton type of change speed box, giving six speeds.

Messrs George Swift & Sons, of Claremont Ironworks, Halifax, exhibited a collection of machine tools, comprising a 10in. centre all-geared head lathe; a 7in. centre high-speed lathe on 7ft. 6in. bed; and 4ft. 3in. and 3ft. 6in. high-speed radial drilling, tapping, and studding machines.

The first-mentioned tool was mounted on a 12ft. box end bed fitted with half-gap, and was driven by means of a 15 h.p.

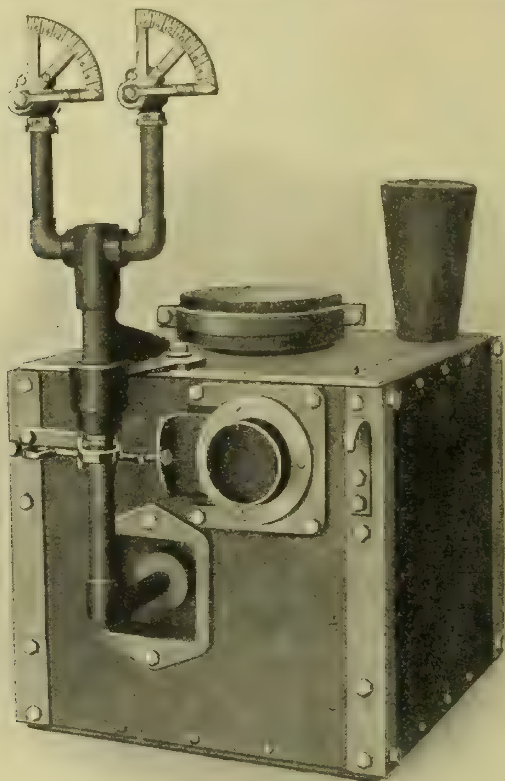


FIG. 2. CRUCIBLE FURNACE. MR. S. N. BRAYSHAW, MANCHESTER.

constant-speed motor. The headstock had a 4⅛in. diam. hole through spindle, and gave 16 spindle speeds in geometrical progression from 8·7 to 135 revs. per minute. All the gears ran in an oil bath, the front and back necks of spindle being fitted with ring oiler bearings, while the thrust of the spindle was taken by Hoffmann's ball thrust washers. The loose headstock was of massive design, and was fitted with a paw which in turn fitted into a rack on the inside of the bed to resist thrust. There were six positive feeds, varying from 8 to 57 revolutions of spindle per inch of feed, these feeds being positive and driven independently of the leading screw.

The headstock of the 7in. lathe had a 1⅞in. diam. hole through the spindle, and was driven by 3-speed cone, two rates of double gears, and 2-speed countershaft, giving 18 spindle speeds from 15 to 428 revs. per minute. Six positive rates of feed were provided, as in the 10in. lathe, controlled by two levers, and the feed shaft was geared up independent of leading screw, the screw-cutting and sliding motions thus being foolproof. The saddle was fitted with double-walled apron, and compound slide rest, accurately indexed for taper turning.

The 4ft. 3in. high-speed radial drilling, tapping, and studding machine was fitted on low base, and with loose box table, and was direct driven by 10 h.p. motor (by Electromotors, Ltd., Openshaw, Manchester), and chain and chain wheels (by Hans Renold Ltd., Manchester). There were 12 changes of spindle speeds obtained through gear box bolted



FIG. 3.—MILLING CUTTER GUARD. MR. S. N. BRAYSHAW, MANCHESTER.

on base, giving spindle speeds from 44 to 489 revs. per minute, all the changes being obtained instantly and controlled by two levers and one star handle. The column carrying arm was mounted on stationary pillar, on which it revolved on roller and ball bearings. The feed box gave four rates of feed, obtained by the movement of one lever, which carried a graduated dial, and the rate of feed could thus be seen at all times without having to refer to an index plate, as usual.



FIG. 4. MILLING CUTTER GUARD. MR. S. N. BRAYSHAW, MANCHESTER.

The 3ft. 6in. radial drill was mounted on box bed and was driven by a 4-speed cone. It was fitted with double gearing, had balanced spindle, rack feed, quick release and reversing motion, and saddle worked along arm by rack and pinion.

Messrs. The British Saw Sharpening Machines, Ltd., of 79, Mark Lane, London, E.C., exhibited their latest designs of automatic saw-sharpening machines, one of which we have

pleasure in illustrating in the accompanying view (Fig. 6). This machine will sharpen any kind of saw, either of the circular, band, frame, hand, or hack type, the action being entirely automatic, and such as can be understood by any intelligent lad. The illustration shows the machine at work sharpening a circular saw; to sharpen band saws an attachment is provided consisting of a frame on which are mounted two pulleys which can be set at any required distance apart on a horizontal bar; these pulleys hold the saw in position and enable it to be revolved past the grinding wheel tooth by tooth. The machine will, it is claimed, sharpen 30 to 40 teeth per minute, and this with a degree of accuracy unattainable by hand, thus ensuring better cutting properties and longer useful life.

Messrs. Schuchardt & Schutte, of 34, Victoria Street, London, S.W., had a very fine exhibit of machine tools, and

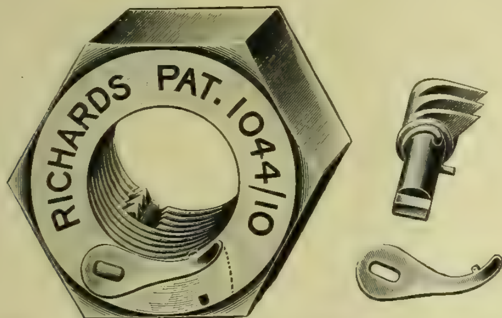


FIG. 5.—RICHARDS PATENT AUTOMATIC LOCK NUT. MR. S. N. BRAYSHAW, MANCHESTER.

made a special display of automatic machines for both bar and chuck work. These comprised principally two "Acme" multi-spindle automatics for bar work, and one "New Britain" multi-spindle automatic for chuck work. This latter we have pleasure in illustrating and describing below. Patent automatic gear hobbing and worm milling machines were also exhibited, together with several of the well-known "Landis" screw-cutting machines. Several new features were to be seen on these, notably the automatic die head and stationary die head fitted to the "Landis" machine, as well as a machine having leadscrew attachment for automatic knock-off. High-speed drilling machines, vertical boring and turning mills, lathes, cold sawing and cutting-off machines, grinding machines, turret lathes, portable electric drills, and the "Shore" pyroscope and scleroscope were also shown, together with a varied range of small tools, &c., and several of these we have pleasure in illustrating and describing below.

Fig. 7 is a photo view of the "New Britain" multiple-spindle automatic chucking machine previously mentioned, while Figs. 8 and 9 show a set of tools used on the machine for turning the drop-forged cam shown in the centre of the tools. A single-head machine, such as we illustrate, was used to produce this cam, entailing two chuckings, one for each end. The time of production for both operations was only four minutes, while the simplicity and ease of replacement of the cutting tools will be noted.

The machines are built in two distinct types, single head and double head. The former are designed for machining pieces which require operations on but one end or on pieces where one end has already been machined, while the double head type handles pieces requiring operations on both ends, accomplishing the result in one-half the time which would be required if each end were finished separately in a single head machine.

As their name implies, the machines have several spindles, ranging from three in the small single head machine to eight in the large double head. The spindles carry and revolve the tools, while several pieces of work are held stationary in the multiple-chuck turret, which, when it indexes, brings each piece of work in line with the next succeeding spindle. All machining operations take place in the intervals marked by the automatic progression of the turret indexing mechanism, the time necessary to complete a piece being measured by the period required for the longest single operation on it. In the case of the single head machine the turret advances and feeds the pieces of work against the revolving tools, while in the double head the revolving tools advance from both sides and form their operations on each end of the work. In this way a series of operations are carried out on several pieces of work simultaneously, the pieces approaching completion as they progress from one tool to another.

The centres of the work-holding sections of the turret are arranged in a true polygon, the axis of the turret barrel being the centre of the polygon. The tool spindle centres are directly opposite and aligned with all but one of the turret section centres on the point of the polygon. As the turret indexes it brings the chuck section opposite where there is no tool, in the most accessible point to the operator for unloading and loading.

In the single head machine the work-holding multiple chuck turret has its chucking sections in line with and facing the tool carrying spindles. The turret is mounted on one end of a rigid turret barrel, which will both turn and slide in two large bushed bearings. On the opposite end of the barrel is the indexing mechanism which automatically locates the turret in its different indexed positions. Directly below the turret barrel and between its two supporting bearings is a large drum mounted on a shaft, which is revolved by a worm gear at the extreme left of the machine. Cam straps are bolted to the outside of this drum and act directly against a hardened tool steel roller on the turret yoke, which may be clamped in any position on the barrel. This yoke adapts the machine for handling different lengths of work, and, in most cases avoids the necessity of any change in cam position or overhang of tools. The angle of the cam straps depends upon the length of feed required on the piece being machined. The balance of the path of the cam changes rapidly to quickly throw the turret forward and back to clear the tools at the time of indexing. Guard straps opposite these reversing portions of the cam prevent the turret from being thrown too

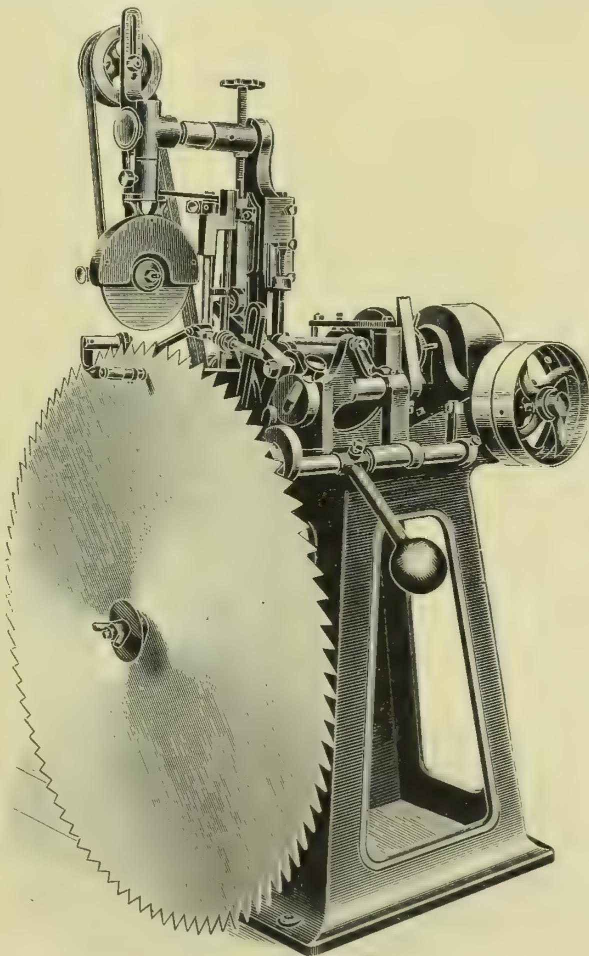


FIG. 6. AUTOMATIC SAW SHARPENING MACHINE. MESSRS. THE BRITISH SAW SHARPENING MACHINES, LTD., LONDON.

far, while an adjustable positive screw stop on the side of the turret yoke accurately gauges the forward movement of the turret.

All turrets have one more chucking section than there are tool spindles. This section is used for loading and unloading without loss of time, while the machining operations are being carried on simultaneously in all the other turret posi-

tions. Each pair of chuck jaws is independent of the others, and is quickly operated by a right and left-hand screw, which has a square end extending for a chuck wrench. The chuck, when equipped with proper shaped jaws, will accurately centre and adequately grip the work. Great care is taken in the machining and assembling so there will be no slackness and backlash in any of its parts, while the screws and chuck jaws are made from crucible tool steel hardened.

Indexing is performed by simple mechanism patterned after the "Geneva Motion," and clearly shown at the extreme

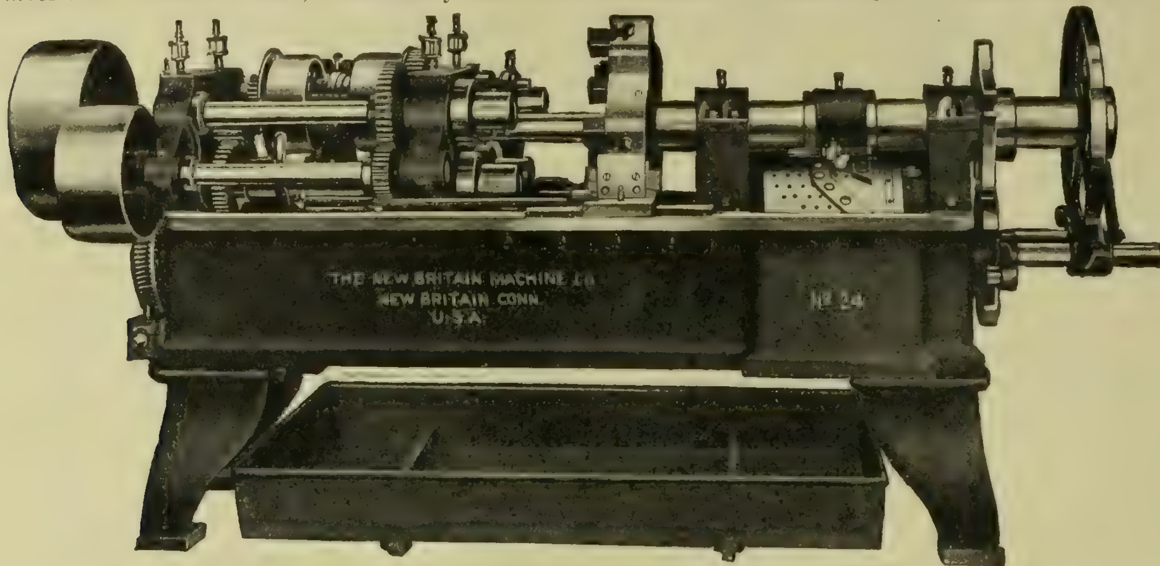


FIG. 7. "NEW BRITAIN" SINGLE-HEAD MULTIPLE-SPINDLE AUTOMATIC CHUCKING LATHE. MESSRS. SCHUCHARDT & SCHUTTE, LONDON.

right of the illustration. This very gradually accelerates the heavy turret at the time of indexing, and as gradually checks its momentum without shock. By making the index dividing wheel twice the diameter of the circle of chucking positions, the accuracy of the index at the work is refined by two. An automatic spring-operated latch defines the turret position when locked in notches in index wheel. There is, however, no strain on this latch, as it serves only to align the slot in the turret, so as to be further locked by the steady rest.

Fig. 10 shows a sprocket drive high-speed cold saw exhibited by the firm which will cut 7in. round material, 6$\frac{1}{4}$in. square material, 12in. I beams on the flat, and will also make angle cuts up to 45° on smaller material. The sprocket drive is the main feature of the machine and removes all strain from the blade spindle as the sprocket drives the saw direct, the teeth gearing into radial slots cut into the blade itself, the spindle merely acting as a guide to the blade, ensuring its running true. The saw arm is raised and lowered by the large worm shown at the right which engages with a quadrant, bolted to the end of same. The worm is lubricated from the inside, and advances the saw arm with a uniform motion, there being no spring when the end of a cut is reached, or in cutting small stock, or even when the teeth come in contact with the work intermittently as they do in certain classes of structural material. A large tank and lubricating pump are also provided from which the oil flows freely to the proper point of the saw blade. To make lubrication doubly sure, however, the blade runs in a riveted steel drip pan suspended from the under side of the arm. The tank entirely surrounds the base of the machine and not only furnishes a large supply for the pump to draw from, but prevents loss and waste of the lubricant.

Shore's pyroscope, as exhibited by the firm, is shown in our illustration, Fig. 11. This is a remarkably simple and efficient instrument, designed for ascertaining temperature by sight, at the same time possessing none of the complications of the recognised optical pyrometer. The standard or basis light is a small kerosene lamp, the flame of which is reflected through a coloured iris diaphragm on to a small nickel silver ball in the telescope. To use, ordinary kerosene is placed in the tank A. The glass door B is then opened, and the wick lighted and adjusted to normal height (about $\frac{3}{4}$in.) by the knob K. The variations of the flame cannot affect the readings unless entirely too low to cover the reflector R, or high enough to smoke. The instrument is now ready for work. By now looking at the hot metals, &c., through eye-piece C, all will be seen as through a telescope. Focus by turning knurled ring E. Next turn knob F, which works the coloured diaphragm and controls the light intensity of the comparison reflector until practically no difference can be seen between the redness of said reflector and the work. This can best be told by going a shade higher or lower until balanced. The indicator H, on graduated drum G, is now looked at and the temperature reading taken. If it is desired to set the instrument at a given temperature figure so that the work can be all heated up to a certain degree, the drum is locked by the set screw M.

Fig. 12 shows a small-size gear hobbing machine exhibited by the firm. The main advantages claimed for the hobbing system of producing gears are that only one cutter for each pitch is necessary, regardless of the number of teeth in the gears; continuous cutting, there being no return stroke and no lost motion; and no intermittent action of dividing gears, the dividing being synchronous with the hobbing.

The drive, as will be seen, is from a countershaft on to a cone pulley. Bevel gear fixed on the end of the cone pulley shaft drives the wheel which is attached to the lower end of the vertical shaft, which drives in turn the spindle through intermediate mitre wheels on the centre of the swivelling hob headstock. Gearing into the bevel gear on the cone pulley shaft is another bevel mounted on a short horizontal shaft

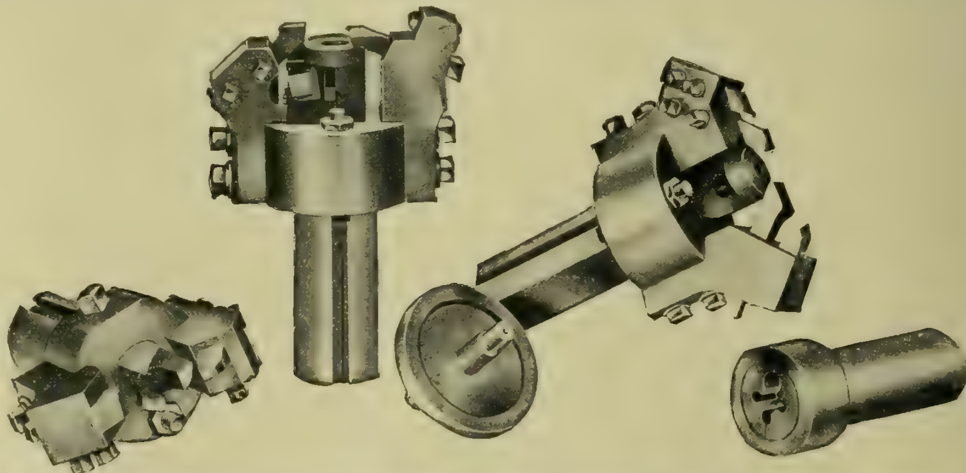


FIG. 8. FIRST CHUCKING, TO TURN CAM SHOWN IN CENTRE, ON MULTIPLE-SPINDLE AUTOMATIC MACHINE. MESSRS. SCHUCHARDT & SCHUTTE, LONDON.

driving the primary train of change gears which actuates the worm drive to the work table. For hobbing spiral gears a patented differential motion is mounted on the abovementioned horizontal shaft, this motion being actuated from a separate set of change gears driven from the feed. The vertical feed to headstock is obtained from a feed bracket through chain to worm and worm wheel, which operates a nut working on a vertical screw of the hob saddle. The feed changes are obtained by using different ratios of change gears and can be altered without affecting the teeth of the gears

being hobbed. The horizontal feed to table, used when hobbing worm wheels, is obtained from the same bracket through chain, worm, and worm wheel, and a revolving horizontal screw and fixed nut. Each of these feed motions can be immediately started or stopped by means of a drop worm.

Messrs. H. A. Harvey & Co., Ltd., Norfolk House, Laurence Pountney Hill, London, E.C., exhibited one of their well-known Harvey oil engines of 6 h.p., and of the horizontal slow speed type, designed to run on low-priced paraffin, with a consumption of 0·675 to 0·5 pint per brake horse-power hour. These engines are exceedingly simple and have no inaccessible parts. They operate on the 4-cycle system, and, being fitted with an auxiliary ignition device, are easy to start. After starting no attendance is necessary, and, as there is no exposed paraffin, absolute safety is thus ensured. Even if the engine be required to run on light or no load for long periods, no lamp is needed.

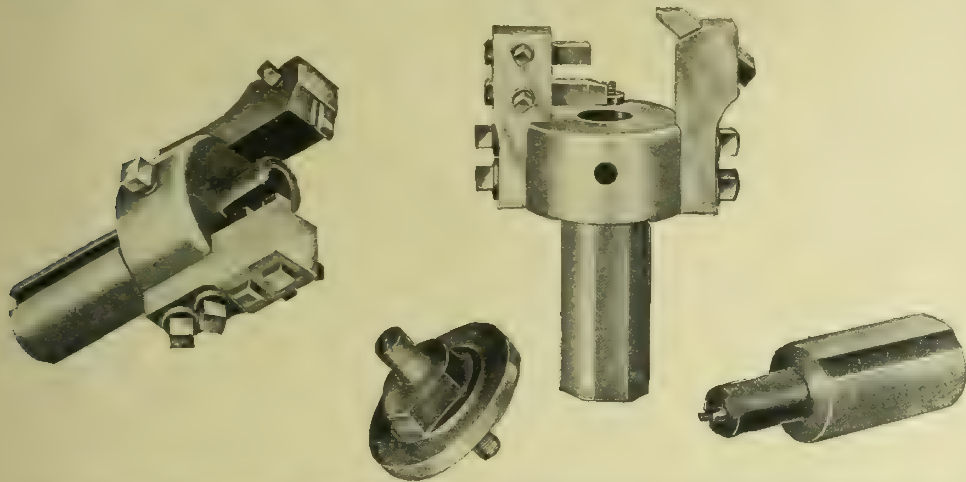


FIG. 9.—SECOND CHUCKING, TO PRODUCE CAM SHOWN IN CENTRE, ON MULTIPLE-SPINDLE AUTOMATIC MACHINE. MESSRS. SCHUCHARDT & SCHUTTE, LONDON.

Other exhibits of Messrs. Harvey & Co., Ltd., were an Ingrey patent automatic weighing and recording machine of 5 cwt. capacity, designed to weigh crushed material from an elevator or conveyer, and to deliver to an elevator or conveyer, both working continuously; a model of a weighing machine to weigh coal or other material delivered from a grab bucket; a "Standard" variety saw bench, and other wood-working machines; together with dry emery grinders, having 8in. wheels; and their well-known "Lamrig" patent spring-lock washers, the latter having been designed for use on all machinery subject to vibration, and capable of being used repeatedly, while causing no sidestrain on the bolts or nuts.

The Ingrey automatic weighing machine is put into operation by the impact or weight of the material falling into the weigh-bucket. This causes the bucket to be lowered gently on to the knife-edged centres of the weigh-beam, records the weight and totalises the same, restores the weigh-beam to its normal rigid condition, opens the delivery doors, discharges the load (keeping the doors open for a sufficient time to ensure complete delivery), closes the doors and locks them, and throws the mechanism out of gear, leaving the machine ready for the successive operation; the whole process occupying from 15 to 30 seconds. This cycle of operation is absolutely automatic, requiring no attendant except for the purpose of occasional cleaning and oiling, and no matter how the load may vary, it is accurately weighed, the weight indicated on the dial, and added to the aggregate recorded, thus showing at a glance the total weight that has passed through the machine.

In the machine shown at the Exhibition recent (1912) inventions and improvements had been introduced, which rendered it even more advantageous than hitherto. Notably the weigh-beams are now provided with a novel arrangement of knife-edged centres, which are visible, adjustable, and removable for repair or renewal. They adapt themselves accurately to the lines upon which the beams oscillate, giving a most perfect balance, and consequently more accuracy in weighing.

The new "Ingrey" recording apparatus is now applied to all "Ingrey" machines, and has been designed specially to obviate the effect of the vibration to which they may be subject, particularly when fixed to non-solid foundations. Although capable of responding to the most delicate balance, this recording apparatus is exceeding simple in construction and free from all liability to derangement. Provision is made for adjustment to allow for the reduction in weight of the weigh-bucket, and its connections, by wear and tear. The machines are standardised, and all essential parts kept in stock. All the above-mentioned improvements are the result of several years' experience under many conditions of working. Every difficulty has, it is claimed, been dealt with, and the machine as now constructed, is offered with perfect confidence that it will fulfil the most exacting requirements, and retain its accuracy during the whole of its working life.

The "Haythorpe" patent feed-water filter and purifier was another speciality shown by the firm. This device makes use of the electro-chemical properties of zinc and carbon, and consists essentially of a cast-iron box in which a number of perforated plates or shelves are fitted, these plates sliding into grooves and thus being kept apart. The spaces between the plates are packed with lumps of coke which thus make intimate contact with them. The water from the hot-well is pumped through these, and the oil, in a saponified state, arrested by the coke. The limes or salts in solution are also acted on, and thrown down in a sludge, and, with the oil, these are periodically blown out into the sump or bilge. Should chlorine or other gases be released, as may be the case where the make-up water is brackish, these also, it is claimed, are absorbed, and released when the filter is blown down. Thus the prime causes of incrustation and pitting are dealt with, and prevented, by the same means that eliminate the oil and other suspended matter from the water. The zinc plates are gradually eaten away in the process and need renewal from time to time, but this can be done rapidly while the filter is "by-passed," new plates being slipped into position and the compartments between filled with broken coke. The filter is simple and compact; the weight inconsiderable, and the space occupied very small. It can be made either vertical or horizontal, of any desired cross-section, and can also be constructed for the highest working pressures.

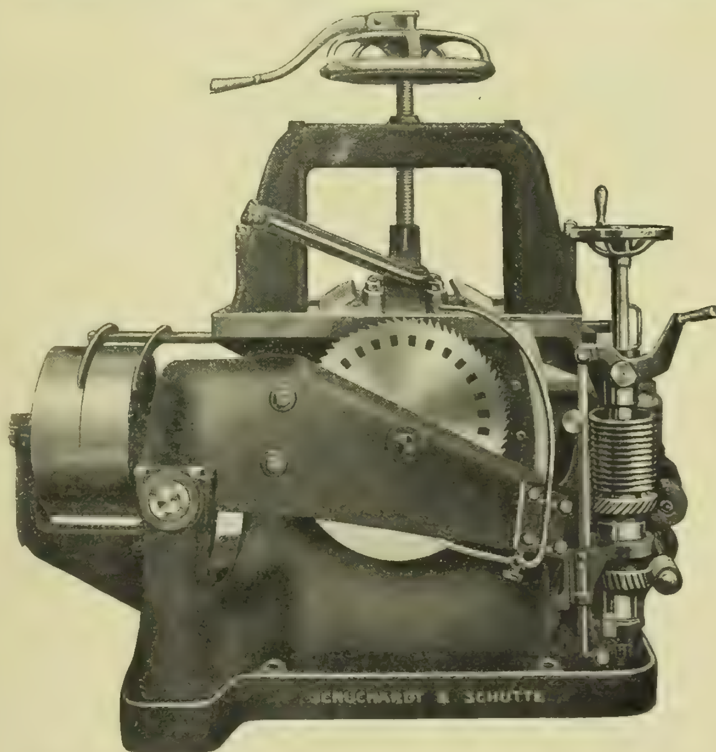


FIG. 10. HIGH-SPEED COLD SAW. MESSRS. SCHUCHARDT & SCHUTTE, LONDON.

Messrs. The Harvey Electro Chemical Company, Ltd., of the same address, showed on the same stand a working exhibit of the

Marino patent cold galvanising process, which we describe at length below, as well as an assortment of china and glass ware, plated with gold, silver, &c., by their patented process. The chief requirements for a satisfactory deposit of zinc are: that the coating is absolutely adherent, ductile, and not liable to flake or peel off; and that it is not porous, so that the iron is entirely protected from outside influence. Most people are aware that the method generally used to give iron a coating of zinc (commonly called galvanising) consists of dipping the iron

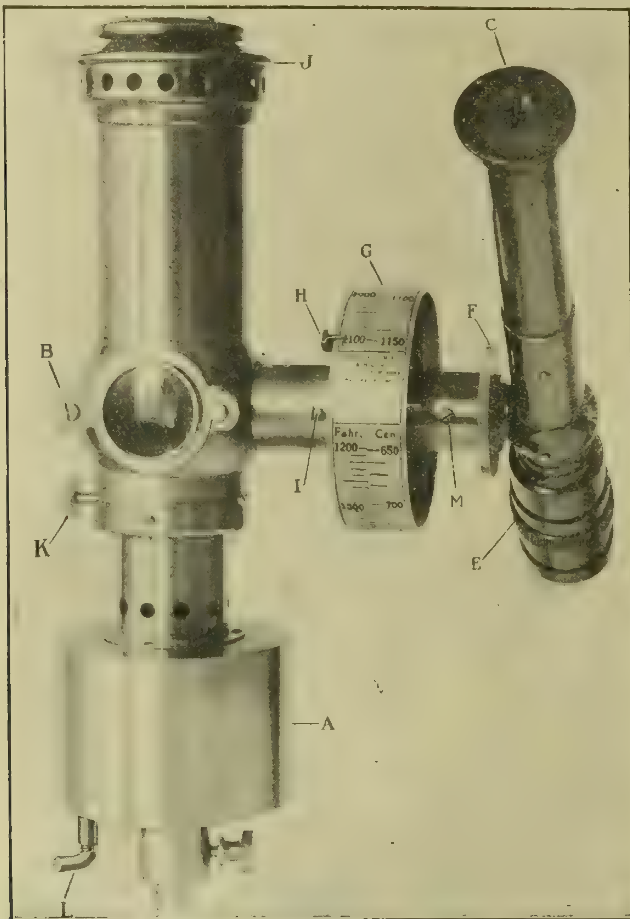


FIG. 11.—SHORE'S PYROSCOPE. MESSRS. SCHUCHARDT & SCHUTTE, LONDON.

into a bath of molten zinc. There are, however, many objections to this method. In the first place, from the nature of the process it is impossible to get an even and smooth coating, and it is equally impossible to regulate the thickness of this coating. Also, as all engineers know, hot galvanising has a harmful effect on the strength and nature of the iron. There are also three serious sources of loss inherent in the hot galvanising method, irrespective of its effect on the article galvanised, viz., that due to the burning of the zinc in the parts nearest to the source of heat; loss from radiation, due to the fact that a large mass of metal must be kept in a molten condition; and loss due to volatilisation on the surface of the molten zinc. Besides these defects the process is an offensive one, due to the production of fumes from the molten metal. Hitherto electric processes have also failed because the sulphate of zinc or other salt has been used as the base in a solution with other mineral acids which themselves act upon the iron treated, so that the zinc is deposited on to a corroded surface, and proper adhesion is impossible. To avoid this, alkaline solutions have been attempted, but these produce a porous coating which is of no real use.

By the Marino electro-galvanising process mineral acids are entirely eliminated and not only is the formation of a corroded surface avoided, but the solution contains an effective reducing agent, which removes any film of oxide that might be present and thus allows the zinc to be deposited on a clean pure surface, so that absolute adhesion is assured. The solution also has a much greater solvent power than those usually employed, so that it is much richer in the required mineral, and as it has the further enormous advantage that it cannot be decomposed under any ordinary conditions, the rate of depositing can be very high. For this reason also the solution remains always constant and never requires regenerating, for the amount deposited at the cathode is always made up by that dissolved at the anode. It is therefore possible to deposit from 1 to 2 grammes of zinc per ampere hour at a pressure of 2 volts, and as this is nearly the theoretical possible, the efficiency is practically 100 per cent. Other processes of electro deposition of zinc require anything up to 14 volts, and only deposit ·5 grammes per ampere hour.

In the process under notice any article of steel, iron (wrought, cast, or malleable), and other metals can be given coatings of zinc or zinc alloys of uniform thickness, and with a clean and regular surface. Further, the coating is very adherent and ductile and not liable to peel off, flake, or crack, even though the metal be severely dealt with by bending, &c. As will be understood, this electrolytic process opens up a field for zinc coating that could never be touched by the hot process. For instance, castings such as valve bodies, pump chambers, &c., steel springs, bolts, nuts, and particularly small screws, &c., which could never be treated satisfactorily by the hot process, are quite easily dealt with by the electrolytic one. The alloys of zinc usually employed are zinc-aluminium and zinc-magnesium. A deposit of these alloys is cheaper than zinc alone and gives a harder coating, whilst a deposit of the two alloys together gives an extremely hard protective coating. With all its other advantages, the electrolytic process has the most important one of cheapness, since

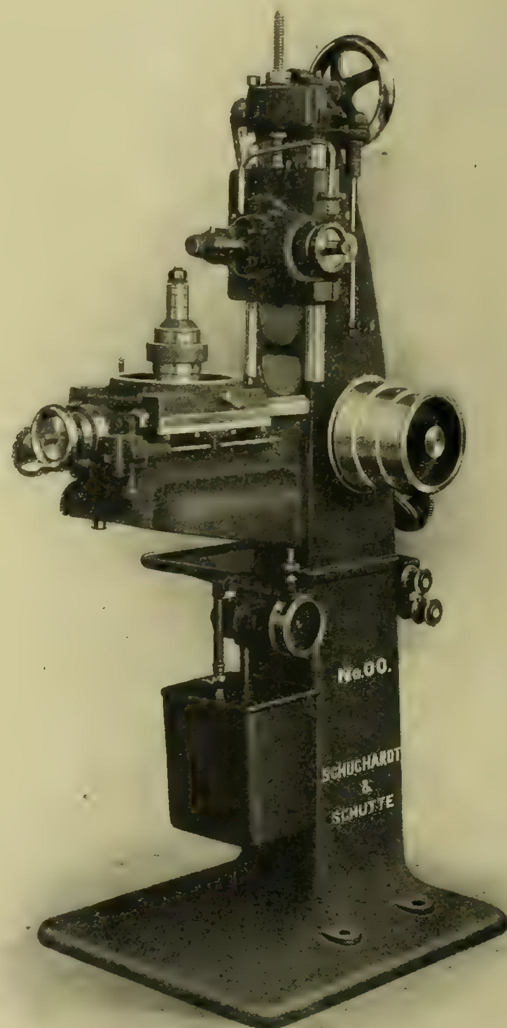


FIG. 12.—GEAR HOBBING MACHINE. MESSRS. SCHUCHARDT & SCHUTTE, LONDON.

the salts are not expensive, the anodes may be of cast zinc, and there are not the sources of loss inherent in the hot process.

The electro-plating of glass, china, and all other normally non-conductive substances, as exemplified by numerous examples of beautiful ware on the stand, is the invention also of Messrs. P. & Q. Marino, and is, we should say, the greatest advance that has ever been made in this branch of electro-

metallurgical science. By the process referred to, an electric deposit is made directly on to the surface of the china, &c., which has previously been prepared in such a manner that the metal adheres to the molecular structure of the base. This is brought about by a liquid which is capable of solving both china and glass, and the metal to be deposited thereon. This liquid or flux holds some of the metal in suspension, and permeates the pores of the china or glass. The metal is then precipitated by chemical reaction, and surrounds the molecules of the china or glass, and the essential for electrical deposition has been attained, as there has been introduced on to the china or glass surface a metallic conducting medium, upon which the metal to be used is deposited. For example, take an ordinary glass salad bowl, treat its edge or rim by sandblasting, or any other method, in order to remove the glazed surface, treat that edge or rim with the patent flux, and suspend the bowl in the silver-plating bath. The rim of the bowl comes out of the bath thickly coated with silver. It is silver mounted, and what is more, it is not a rim of silver cemented on to the glass (which is the present method of attaching such rims), but a silver rim which is an integral part of the bowl, and it can only be separated from the bowl by breaking the glass itself. A more striking example, perhaps, is that of plating an ordinary china teapot. After the teapot has been duly prepared and treated in the same manner as before described, and placed in the plating bath, it comes out in due course, not, as originally a china teapot, but a beautiful silver one, with the further important advantage of having a glazed china lining. This important advantage is really two-fold : first, from the point of view of cleanliness, and secondly, from the undisputed fact that tea is better brewed in earthenware than in metal.

Messrs. United Machine Tool Works, of 133, Upper Thames Street, London, E.C., had a large and interesting exhibit of machine tools, including high-speed turret and engine lathes, radial and sensitive drilling and tapping machines, shapers, hacksaws, portable hand cranes, power filing machines, tool grinders, and pneumatic power hammers, and from amongst these we select the latter tool and one of the high-speed drilling machines for special description.

The hammer, two sizes of which are shown in the illustration (Fig. 13), is claimed to be the most simple, reliable, economical, and efficient one on the market, and is the result of 20 years' practical experience. It is under perfect control, delivers heavy or light blows, and these can be struck singly or in series, as desired, and rapidly, or at intervals. As will be seen, the body consists of one large casting, hollow, but strengthened by cross ribs. The drive is either transmitted by belt to fast and loose pulleys, or in case of electric drive the motor is mounted on a side bracket, as shown, and instead of the fast and loose pulleys a large gear wheel is provided. The slanting position of the link is one of the firm's latest improvements, this having the effect of accelerating the downward stroke, whilst taking less power for lifting the tup and piston. The hammer is regulated by one lever only, which controls two valves simultaneously, and by pressing this controlling lever right down, the tup is held in its highest position, whilst the cylinder continues to swing. The hammer can also be used with great advantage as a vice, and when so used the tup is not merely held down by air pressure, but is firmly held in position by a brake which is controlled from the same lever which regulates the force of the blows.

Substantiating their claim that the hammer takes less power than any other pneumatic hammer on the market, the firm state that with their hammer having a falling weight of 4 cwt. and driven by a 9 h.p. motor they are able to stretch within three minutes a piece of Siemens-Martin steel from 10¾in. by 3½in. to 5ft. 6in. by 1¼in., whereas a vacuum hammer of equal falling weight, driven by a 12 h.p. motor and running at a speed of 190 revs. per minute was only able to stretch the same piece of steel under the same conditions to 3ft. 6in. by 1¼in. The hammer has only one cylinder and therefore very few wearing parts, and practically no power is consumed when it is running free.

The high-speed drilling machine, which we regret we are unable to illustrate, possessed several important features, chief of which may be mentioned the quick adjustment of the sliding head and boring spindle, the working of which was as follows: After the drill had been fixed, and the automatic stops had been adjusted for limiting the drilling depth of the drill and the quick adjustment of the spindle and sliding head, the operator threw the feed motion of the sliding head in by shifting the lever at the foot of the machine. After this the operator had only to reverse a lever in front of the sliding head, when it, with the boring spindle, travelled at a speed of 5in. per second towards the work, and stopped instantly in front of it. By reversing the above-mentioned lever on the sliding head again, the ordinary self-acting drilling feed of spindle set in, and as soon as the desired depth had been attained, the feed of the boring spindle and sliding head was automatically disengaged and the latter remained stationary. The operator then threw in again the quick adjusting feed of the sliding head and spindle, by shifting a lever at the foot of the machine and by giving the sliding head a slight touch, it again returned with a speed of 5in. per second back to its highest position, when the process was again gone through. This arrangement, it will be seen, is a great time saver where much repetition work has to be done. Four different spindle speeds are provided, but the quick adjustment speed remains the same (viz., 5in. per second), no matter at what rate the machine is running.



FIG. 13.—PNEUMATIC POWER HAMMER. MESSRS UNITED MACHINE TOOL WORKS, LONDON.

Messrs. The Oxygenite Syndicate, Ltd., of 64, Victoria Street, Westminster, London, showed various types of generator used in their process for the production of oxygen. This process does away with the necessity of storing oxygen in steel cylinders, as the gas is stored in a powder, called oxygenite, from which it is released by the slow combustion of the powder in generators. Oxygenite is non-explosive,

non-percussive, and not affected by water; and it can be stored indefinitely. To obtain oxygen, a metal container is filled with oxygenite, placed in a generator, lighted, and the cover of the generator screwed home. Oxygen is then ready for use in 5 or 6 minutes. Weight for weight, it is claimed that oxygenite stores about six times as much oxygen as a steel cylinder. A great saving in freightage charges is thereby effected, when compared with the method of storing oxygen in steel cylinders, which, when empty, have to be sent back to the oxygen factory to be recharged, and then carried back again to their work. As showing the amount of oxygen that may be obtained, we may mention that with one of their type E generators a charge of 18½lbs. of oxygenite liberates some 89 cub. ft. of oxygen at a pressure of 300lbs. per square inch. The combustion chamber in this type of generator can be cut off from the storage chamber, and in this way the generator can be re-charged whilst still delivering a supply of oxygen, thus working continuously. This type will easily deliver 100 cub. ft. of gas per hour, and should prove a very convenient size for ordinary shop use.

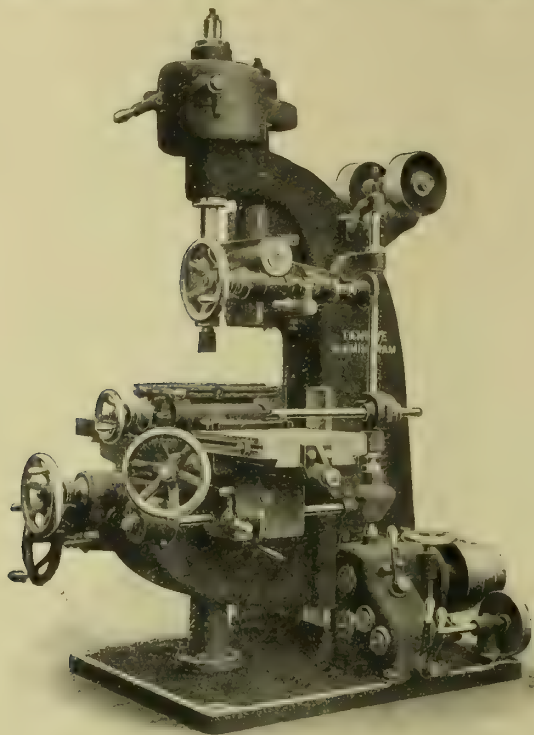


FIG. 14.—No. 3 VERTICAL MILLING MACHINE. MESSRS. TANGYES, LTD., BIRMINGHAM.

Messrs. The Herbert Frood Company, Ltd., of 39, Upper Rathbone Place, London, W., exhibited samples of their well-known speciality in the shape of "Ferodo" fabric brake linings. This is a fabric of great mechanical strength, and recognised by the Board of Trade for all brakes on the London Electric Railways, where previously incipient fires were due to the ignition of metal brake dust. "Ferodo" linings are, it is claimed, composed of chemical affinities, which mature under heat friction, and form a bond which thus cements the fibres together, and prevents abrasion of the surface and formation of escaping particles (which friction would ignite). The bonding—a patented feature—and the rapid diffusion of heat peculiar to the fabrics constitute a non-sparking surface. The "Ferodo" coefficient ·5 rising to ·7 is not affected by oil or water, and the brake lining engages and releases instantly with smooth rising power. It is cheap to use, and its durability is many times that of hard oak. The linings last longer than metal of even thickness, save labour and time, and, being non-abradent, the drum surface is maintained highly polished and true.

Messrs. Tangyes, Ltd., of Cornwall Works, Birmingham, exhibited four large machine tools of their manufacture, viz.: A 5ft. high-speed pillar type radial drilling machine; an 8in. single-pulley all-gear sliding and screw-cutting gap lathe; a No. 3 vertical milling machine; and a 10in. centre capstan lathe; and as representative of these, we illustrate the two latter machines. Fig. 14 shows the vertical milling machine, which, as will be seen, is a massive, yet withal compact, tool. It has been designed for using high-speed steel, and possesses several interesting features, amongst which we may mention the following. It has automatic horizontal feeds to table, and vertical feed to spindle, with stop motions. The table is raised and lowered by hand, and provided with T slots and trough, the hand motions being fitted with micrometer adjustments. A large range of feeds in geometric progression, driven from countershaft, are fitted, and these have changes effected by conveniently-placed levers and handwheel, and are provided with a reversing motion. There is also a large range of spindle speeds, and the spindle is balanced by counterweight. The circular table is readily detachable, is indexed to degrees, and is provided with self-acting and hand feed having automatic knock-off motion. An attachment for tightening the driving belt is also fitted, and the spindle may be driven either direct from the belt or through the back gear.

The 10in. capstan lathe exhibited is illustrated in Fig. 15. This machine admits 48in. between the hexagon turret and the chuck, and has been designed for producing repetition work from bars, castings, or forgings. It has a headstock of the all-gear, single-pulley type, and thus the full power of the lathe may be maintained, irrespective of the diameter of the work being machined in it. Friction clutches are used for starting and stopping, and handles are provided for changing gears, which are all interlocking. The turning saddle, as will be seen, has a square turret for carrying four tools, has self-acting interlocking sliding and surfacing motion, with automatic stops, is arranged so that four different threads can be cut from one leader, and has reversing motion to the feed. The turret is 11in. diam. across the flats, the bed is 16½in. width, and the hole through the spindle is 3⅝in. diam. The turret is provided with automatic revolving and stop motion, and the lathe is provided with suds pump and tray for supplying lubricant to the cutting tool, as shown.

The high-speed drilling machine shown (not illustrated) was driven from a gear box through pulley running at constant speed. Sixteen changes of spindle speed were provided for, the double gear being carried on the saddle itself, and four changes of self-acting feed, all effected by means of levers. Self-acting stops were fitted which could be set so that the spindle could be stopped after drilling any predetermined depth of hole, and a fine feed to the spindle and quick return by hand were also arranged for.

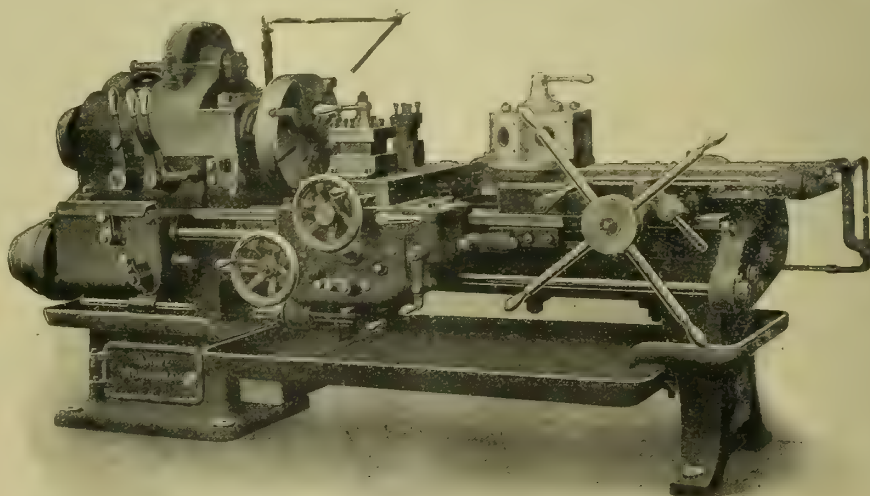


FIG. 15.—10IN. CAPSTAN AND TURRET LATHE. MESSRS. TANGYES, LTD., BIRMINGHAM.

Messrs. The Hudson Economiser Company (1907), Ltd., of 110, Bishopsgate, London, E.C., exhibited two working models, an

open type and an enclosed chimney type water cooling tower. Externally these are of familiar appearance, but the grid arrangement has been considerably improved. The water overflows from troughs and drips on to staggered wooden strips, which are of special construction. Three strips go to form a hurdle, and these can be instantly removed independently of the others. The arrangement breaks up the water most efficiently, as there is no clear drop of more than a few inches. Cooling towers of the above type, it is claimed, may be built considerably smaller for an equal duty than some of the older forms.

Their patent combined feed-water heater and oil separator was also shown on the stand. This is well known amongst all steam users where a large and copious supply of hot water is necessary in works, such as breweries, laundries, dye works, &c. Their latest addition is for heating air by exhaust steam or live steam for drying materials, heating buildings, factories, &c. The heater consists of a number of flat, hollow, galvanised steel plates assembled together in flat groups or batteries, and connected up so that the steam may pass into and through the whole series. The steam is by this method split up into thin layers, a fan or blower forces the air between each unit, and the water of condensation falls to the bottom of the plates and thence to a drain pipe. The capacity of the condenser is enlarged by the addition of more units and vice versâ. In each cubic foot of space occupied by the condensing battery there is no less than 38 sq. ft. of effective surface. The apparatus may be fixed vertically or horizontally with equal results, and the air, after passing through the units where it absorbs heat, is available for warming and drying purposes, and is thus of double service.

Messrs. The Messer Engineering Company, of 296-300, City Road, London, E.C., exhibited a fine collection of autogenous welding and cutting plants, practical demonstrations being also given from time to time at the stand in the welding and cutting of various metals. Blowpipes were shown, capable of cutting iron and steel from ⅛in. up to 12in. in thickness, together with regulating valves, stationary and portable acetylene generators, hydraulic back-pressure valves, &c. An exceptionally fine collection of samples of work done with the "Messer" appliances was also shown, including artistic metal work for iron gates, railings, chandeliers, &c., as well as samples of welding of wrought iron, sheet iron, cast iron, steel, copper, nickel, aluminium, &c.

Messrs. The Eyre Smelting Company, Ltd., of Barden Road Works, Tonbridge, Kent, exhibited samples of their "Eyre" anti-friction bearing metal, for lining all classes of bearings, in ingot form; and also brasses of different descriptions lined with this metal. "Eyre" valve metal was also shown, this latter being especially suitable for lining slide valves, &c. Cheaper quality bearing metals, suitable for machinery bearings running at medium speeds with medium loads, were also to be seen on the stand. The company have just brought out a new descriptive catalogue on the "Eyre" metal, and this will, we are told, be sent free on application, together with samples of the metal.

Messrs. Holbrook & Sons, of 44, Martin Street, Stratford, London, E., exhibited four lathes of their standard make, viz., one of 8½in. centre; two of 7in. centre; and a fourth of 6in. centre. The first mentioned was of the all-gear type, and had 16 spindle speeds in geometrical progression. It was fitted with the firm's fool-proof feeds, and had independent front shaft absolutely independent from the leading screw, which is their standard practice. This machine, which weighed about 5 tons, is, we believe, about one of the heaviest, if not the heaviest, type 8½in. centre lathe made.

The 7in. T. B. type lathe shown was a new departure designed principally for tool room use. The accuracy of this machine, which was fitted with an automatic screw-cutting device, is guaranteed to be ·001in. per foot in alignment. It is, we should say, one of the most up-to-date machines the firm has yet constructed. The feeds were from 8 to 450 per inch, and threads from 1½ to 80 could be cut without any loose change gear.

Messrs. J. Butler & Co., Ltd., of Victoria Ironworks, Halifax, exhibited one of their well-known high-speed planing machines, such as we have previously described; a 30in. duplex boring and turning machine with heads of the octagonal bar type; a 12in. stroke slotting machine; a 16in. stroke crank shaper; a 10in. centre lathe; and a patent bar cutting-off machine. This latter machine was capable of cutting off round bars in iron or steel up to 9¾in. diam., and could either cut a long bar in two, or cut a disc off the end the bar being held stationary in strong vices, and the tool being made to revolve round it. Three sizes of machines are, we understand, made, viz., to cut up to 6in., 9¾in., and 14in. diam. respectively.

The duplex boring and turning machine referred to above was of entirely new and somewhat unique design. Each table could be started or stopped instantly by a lever in front of the machine, and they were independently driven by belt from lineshaft to a speed gear box, a separate geared box being provided for each headstock. The headstocks were mounted on two absolutely independent cross-slides, so that they could be operating on different heights of work without overhang.

THE GENERATION AND ELECTRICAL TRANSMISSION OF POWER FOR MARINE TRANSPORTATION.*

BY WILLIAM P. DURTNALL.

(*Concluded from page 626.*)

THE steam turbine is the most satisfactory prime mover now in existence for high powers, and will remain so until the gas turbine is developed, especially as the high-speed turbine can be made to take advantage of high temperature steam. It also possesses the advantages of light weight and simple construction, has only one moving part, is silent in operation, produces a constant even torque, requires no lubrication in the steam spaces, and has a high fuel economy, even under tremendously varying loads. It has, however, important disadvantages; firstly, having to be direct-coupled to the propeller, it must run at a relatively low speed, thus affecting the fuel consumption to a very serious degree; further, the application of the turbine to direct propulsion embodied the idea of raising the speed of the propeller, and this, for reasons already mentioned, increased the losses at the propeller in developing a certain amount of thrust, which again increased the horse-power necessary to develop it, and consequently the fuel consumption per effective thrust horse-power. This limitation of the number of revolutions demanded increase in the size and weight of the turbine and did not permit of the use of superheated steam; consequently most marine turbines at the present time use saturated steam, which is one reason why the marine direct driving turbine uses about twice as much steam per brake horse-power as one of equal power and higher speed, using superheated steam and high vacuum, in power stations on land.

Further, the turbine is not reversible, and consequently in order to have a full power reverse on the shafts it is necessary to install the turbines in duplicate. Where there are three shafts reversing power has been sacrificed, being provided only on two of the three shafts, and even this power is only a portion of the total ahead power provided on such shafts; and further, these so-called reversible turbines are very uneconomical in steam. At the same time, practical seagoing conditions require that the machinery shall be live when proceeding, say ahead, at full power and speed, whereas, in that condition the reversing turbines are being run and driven by power from the ahead turbines, thus taking a considerable amount of power which should be used for propulsion. Moreover, the extra turbines and pipework occupy a great deal of space and the valve operation for reversing involves waste of valuable time. Even then the reverse is very weak compared with ordinary marine steam engine driven propellers.

A paper by Mr. Thomas Bell, M.I.N.A., designer of the plant for the "Lusitania," states that when this boat entered the measured mile at a speed of 22·8 knots (the full speed ahead of this boat is about 26 knots), the propellers turning at 166 revs. per minute, the engine-room telegraphs were rung for "full speed astern," and nearly four minutes were taken to bring the vessel to a standstill, in which time she ran a distance of three-quarters of a mile or about six times her own length. If the vessel had been under full draught at 26 knots she would, in the author's opinion, have travelled quite a mile and a half. It should, however, be noted that this vessel has reversing power only on the two inner of her

* Paper read before the Society of Engineers, November 4th, 1912.

four shafts, which were driven by six turbines. It has been stated on good authority that had the ship been fitted with modern slow-speed reciprocating engines on, say, three instead of four shafts, the thermal propulsive efficiency would have been increased, and that only 53,000 s.h.p. instead of 70,000 s.h.p. would have been required to give the vessel the same speed.

The turbine being most efficient at the lower pressure end, what is known as the combination system has been tried on some vessels, including the ill-fated "Titanic." It consists of driving three propellers at low speed, the two outer ones being driven by reciprocating engines, which exhaust into a low-speed low-pressure turbine driving the centre propeller. This system gives a lower fuel consumption per thousand tons of displacement per mile at a given speed, and better thermal propulsive efficiency whilst going ahead at full power, but even so reversing power has been sacrificed, being available only on the two wing shafts, and, in the author's opinion, this method is not as safe and efficient as the system of electrical propulsion which he has introduced under the name of the "Paragon" system. In developing this system a low-revolution speed was decided upon in order to get as much thrust per shaft horse-power as possible, and the question then arose of what method should be adopted for driving the propeller; should it be a steam turbine, reciprocating engine, oil, or gas engine? Limitations were found as regards the fuel consumption, in the application of the turbine, unless some form of gear reduction were used, and on further enquiry it was ascertained that manufacturers here and on the Continent were not in a position to guarantee such mechanical gears to run silently permanently as required.

Without a complicated system of change-speed and reverse gears and clutches it would have been essential to regulate the speed of the turbine, and to put in another turbine to give a full power reverse, and thereby to ensure safety at sea, especially on a heavy ship at high speed. On approaching the question of using reciprocating steam engines with forced lubrication and superheated steam, many difficulties were met, especially those common to all heavy reciprocating masses in motion, and the losses were still considerable. Almost the same applied to the internal-combustion engine, with the further serious defect that on account of the compression this engine could not be run at a suitable dead-slow speed. With a heavy oil engine at slow speed complete combustion could not be effected, and cylinder deposit would have taken place, which, in addition to other considerations, forbade the use of the direct-coupled internal-combustion engine for this system of ship propulsion.

Knowing that, if necessary, it would be possible to design and construct electric motors which would run equally efficiently in either direction with a speed range from zero to maximum with variable voltage, the continuous-current system then came under consideration, and was favourably viewed because such motors are self-starting and develop a heavy torque at starting, which is a considerable advantage if it should be necessary to reverse the propeller when at full speed ahead.

Having gained considerable knowledge in connection with petrol electric motor-cars of the trouble that might be experienced with the continuous-current system, attention was next directed to the polyphase alternating-current method, in which the troubles of commutation and other difficulties were wanting, and a scheme was prepared on these lines, in respect of which patents were granted in 19 countries in 1905. The system as then laid out has now been installed by the General Electric Company on the United States twin-screw collier "Jupiter," of 20,000 tons displacement and about 6,000 h.p. The turbine will run at 2,000 revs. per minute, and by putting more poles in the motors than in the generators electrical speed-reduction gear can be formed so that the maximum of thrust can be secured with slow-running screw propellers, thus reducing the shaft horse-power required. Thermal losses naturally take place in transforming the mechanical power of the turbine into electrical power, and then transforming this back at slow speed in the motors into mechanical shaft horse-power, but shop tests indicate that the steam consumption per shaft horse-power at sea will be about 11·25lbs. per hour, which is 20 per cent. less than her sister ship the "Cyclops," of the same tonnage and approximately the same designed speed.

It is probable that an even higher speed than that estimated will be attained or that the steam consumption for the same speed will be lower on account of the saving in weight of machinery. The weight of machinery in the steam-driven boat is 280 tons, whilst that of the electrically-propelled ship is only 156 tons, and with the same dead weight of freight, less displacement will be shown.

A third vessel named the "Neptune" is under test in America, and is driven by twin-screws, and with what is called a geared turbine, as advocated by the Westinghouse Company of America. The mechanical method of speed reduction in large powers is limited. Propellers are to be run at, say, 135 revs. per minute in the case of the "Neptune," the turbine revolutions being only about 1,250, a contrast with the electrically-driven vessel, in which there is practically no limit to the speed at which the turbine may run. On the "Jupiter" the normal speed is 2,000 revs. per minute, the turbines being lighter and less costly with a better thermal efficiency, and consequently a lower steam consumption per horse-power hour, than the geared turbine installation. The full particulars of the "Neptune" trials have not yet come to hand, but the turbine speed was 1,250 revs. per minute, and that of the propeller 135 revs. per minute, and the trials showed a performance much inferior to that of the "Cyclops." It can therefore be assumed that mechanical reduction of speed is here out of the question, although attempts have been made to alter the turbines and propellers, but unless the ratio is made as large as that of the "Jupiter," namely, 18 to 1, instead of the $9\frac{1}{4}$ to 1 of the "Neptune," the latter can never be so efficient, and any improvement in the design of its turbines or propellers can be equally applied to the electrical boat, which will then still hold an advantage in respect of thermal efficiency in addition to all its other merits.

The turbine not being reversible, separate reverse turbines have to be installed, thus adding to the weight; further, the stress on toothed gearing increases with the shortening of the teeth in the pinions, and this limits the practicable gear reduction ratio. On the other hand, the length of the pinions and wheels is limited by the torsional elasticity of metal, and disaster might occur by reason of unequal distribution of the tooth load through the tooth length. The shock and strain developed in teeth is increased by raising the peripheral speed, and this again limits the turbine speed for a given pinion diameter and power. Increased diameter and larger power in gears produce vibration and noise which are likely to be noticeable in distant parts of the ship, and to cause certain defects. To gear the turbines to the propeller shaft means that the boiler equipment must be in close proximity thereto and therefore either that the weight must be well aft, or that thermal losses must occur in the transmission of steam from the boilers to the turbines, while other drawbacks are to be anticipated.

The system installed on the "Jupiter" is being fitted up in the manner advocated by the author with a reduction ratio obtained by providing the generators with a less number of magnetic poles than the motors, while in order to start the motors from standing, and to develop sufficient torque to reverse the propellers when necessary, the rotors of the induction motors have been fitted with slip rings. The current is generated at practically constant frequency and voltage, which although working well in the present instance, with two 3,000 h.p. motors, might conceivably cause serious trouble in very large powers, as in the case of liners and battle-ships, where the power may be as much as 25,000 h.p. per shaft. With this in view the author carried out some experiments which proved the value of the induction motor known as the squirrel cage motor, a device which is an important factor in the successful propulsion of ships by electricity, and meets with the approval of many practical marine engineers.

This squirrel cage motor is the most efficient motor in existence and like the turbine has only one moving part. Its very simple design and construction combined with its great mechanical strength is likely to bring it into high favour for electrically-propelled vessels; it has no slip rings or brush gear, the whole of the current in the rotor winding being induced across one air gap, which is a tremendous advantage, especially with large powers. This motor has no sparking limit, as is the case in all contact conduction machines, consequently the output in mechanical horse-power per unit weight is much higher than in any other type of electrical

machine, with gain in efficiency. A very large section is given to the windings of these machines, which together with the fact that the windings are arranged so that copper losses are not localised, and that iron of a laminated character is used in the construction of both rotor and stator, gives every facility for ventilation. Burnt out armatures and the turning of commutators are the bug-bears of all engineers operating heavy electrically-driven machinery, but these defects are almost unknown in the case of the squirrel-cage motor. Its only defect, and the reason why it is not generally used throughout the world, is the fact that at the time of the author's first investigations, it was not able to start on load, or to produce even sufficient starting torque in large powers to start itself light. When standing, and being supplied with high frequency current it acts only as a short-circuited alternating-current transformer. If the difficulty of starting could have been overcome this motor offered an ideal method of driving propeller shafts for ship propulsion.

In 1908 the author took out patents in many countries for a method of generating current at variable frequency and voltage, and under these patents was evolved an efficient squirrel-cage motor. At starting a very heavy torque is developed by such motors if they are supplied with a much lower frequency current than is used for running them at top speed and full power, and cumbersome and wasteful water or other resistances are not required either for reversing or speed regulation; moreover only three leads or cables are required between the controller and the motors, and the weight of the motor per unit power is low, while the heat losses are less, thus adding little to the heat of machinery rooms below water level. The working current from the generators is supplied only to its one part, which is stationary, so that no rubbing contacts of any kind are required, and the motor can work in almost any position. It has only one winding and the winding space is very small, consequently the teeth are short, and there is a highly efficient magnetic circuit. If supplied with lower voltage as well as lower frequency, the magnetising currents are reduced, and the motor will run for months on end, with high efficiency, at practically any speed and power, while the first and running costs are low. These are some of the reasons for the adoption of this motor in connection with the Paragon system of ship propulsion, as there exists at present no other so simple and strong a mechanical machine for driving propellers, as well as auxiliary machinery of all kinds. This motor meets all the conditions laid down on p. 626 ante, and as regards the method of supplying current the polyphase alternating-current system has been found to answer the purpose most satisfactorily.

The use of electricity for the propulsion of large ships was a matter which had to await the advance of engineering science and the production of suitable prime movers, and a few years ago the proposals could not have attained a commercial success, but, to-day, with the steam turbine, the internal-combustion engine, and in the very early future the gas turbine, the means are at hand for driving the generators to produce current for the use of the shaft driving motors. Ship propulsion by electricity, therefore, has been until quite recently looked upon by many engineers, who have perhaps not had cause nor inclination to investigate the problem, as impossible. Generally speaking, marine engineers and naval architects have not kept pace with the great advance of recent years in heavy electrical power engineering, and consequently they could not appreciate any persistent attempt to solve the problem. On the other hand, electrical engineers are largely unacquainted with the intricacies of naval architecture and marine engineering such as the question of screw propeller losses when run at high speed. Until quite recently it has been maintained that a high-speed propeller was as efficient in producing thrust as a low-speed one, and so the propulsion of ships by electricity made no advance, many electrical engineers openly condemning the scheme as uncommercial.

Great credit is therefore due to Admiral Cone, of the U.S. Navy, and his colleagues, who have in hand the equipment of the "Jupiter" on behalf of the American Government, and also to Mr. W. L. R. Emmet, of the General Electric Company, of America, the designer of the plant for the "Jupiter." Mr. Emmet is also the chief turbine engineer of the above company, who build the direct-coupled Curtiss turbine, and consequently his knowledge of both methods of propeller driving makes all the more certain of the fact that the general adoption of electrical power for ship propulsion is nigh at hand. Mr. Henry A. Mavor is also engaged on the equipment of a 600 h.p. electrically-driven ship, on the lines indicated, but in this case the prime movers are two 300 h.p. Diesel engines running at 400 revs. per minute and supplying 3-phase alternating-current to one squirrel-cage induction motor driving the propeller at 78 revs. per minute. This ship will undergo her trials at approximately the same time as the larger "Jupiter," the results of which will be awaited with interest. It must also be mentioned that Mr. A. J. Maginnis, M.Inst.C.E., of Liverpool, as far back as 1909, entered into a contract for the conversion of a large ship on the Paragon system, but the matter fell through for reasons beyond Mr. Maginnis' control.

Much interesting research work and designing has been carried out by Dr. Hele-Shaw and Mr. Holzapfel in this country, and Dr. Fottinger in Germany, as to the method of hydraulic power transmission between the high-speed non-reversing prime mover and the reversible and efficient low revolution speed propeller for propulsion purposes, and I recently inspected a most interesting set by Dr. Hele-Shaw at the Engineering Exhibition, and also his very fine steering gear, both in this country and at Trieste, in Austria, where it is giving great satisfaction.

There are not lacking signs that British shipping is feeling the competition of other countries, which are introducing new and more efficient means of propelling ships. The actual ships in hand, and the papers that have recently been read before American and continental societies of naval architects and marine engineers, show that the electrically-driven ship has now become a matter of more than academic interest. The successful results which may be achieved by the "Jupiter" may even change the naval programme of more than one Great Power, and it is to be hoped that the British Government will take a wide and unprejudiced view of the real position which has been created.

HARDY'S TWO-STROKE INTERNAL-COMBUSTION ENGINE.

Several arrangements of two-stroke-cycle internal-combustion engines of the sleeve type, the invention of Mr. J. A. Hardy, 6, Avenue Jules Janin, Paris, are shown in the accompanying sectional views. They have been designed with a view to effect a better scavenging of the burnt gases, to improve the conditions of ignition and to effectively cool the sleeve-extension.

In the construction, shown in Fig. 1, the piston A is extended upwards in the form of a cylindrical sleeve and has rings of ports B for the exhaust and C for the admission, corresponding to rings of ports D and E formed in the wall of the cylinder; the ports D lead to the atmosphere, the ports E communicate with a channel F by which the mixture is received from any suitable apparatus under pressure sufficient for the scavenging. This apparatus may consist of the closed crank case acting as a pump body, a pump, a fan, or any other suitable device. The cylinder is surmounted by a head G, in which the sleeve extension of the piston A fits. Packing rings are arranged at suitable points on the piston and the sleeve. Ignition is effected by means of a sparking plug H. The head of the piston A to which the sleeve is connected has a generally conical shape, that is to say, it is bounded by inclined surfaces, the lowest points of which connect with the inlet or exhaust ports while the highest point is at the centre of the piston, that is to say, upon the centre line of the cylinder; the stationary end of the cylinder is given the same shape.

In the construction, represented in Fig. 2, the sleeve is given a diameter different from that of the piston A, so that the head G has a smaller bore than the cylinder. In this way there is formed an annular chamber J, which may be utilised as a pump body to compress the mixture before admission to the cylinder, or as means for cooling the sleeve. For this purpose, slots K are formed in the wall of the cylinder. In this construction also the sleeve has been given a constricted shape towards its lower end, corresponding to the expansion curve of the mixture admitted under pressure and allowing a more thorough scavenge of the burnt gases.

By adopting the arrangement shown in Fig. 3, in which the cylinder occupies the position opposite from that which it had previously, it becomes possible to utilise the top of the cylinder and the piston as a pump for inducing the carburetted mixture through a pipe L with non-return valve and for compressing the same.

The arrangements shown in Figs. 2 and 3 allow of obtaining an effective cooling of the sleeve; when the piston moves in the cylinder during the expansion stroke, the crown acting somewhat in the manner of a pump draws in atmospheric air through the ports K (Fig. 2); this air fills the space J between the cylinder wall and the sleeve wall, and is then expelled during the following stroke, viz., the compression stroke, being then replaced by fresh air when the piston again descends after the next explosion. The sleeve wall is, therefore, in direct contact with the air which is constantly renewed, so producing a very effective and thorough cooling of the sleeve.

In two-stroke engines the mixture is usually compressed either in the crank case of the engine or by means of a pump before admission to the cylinder; the mixture then expands at the moment of admission because the cylinder is at that instant in communication with the atmosphere through the exhaust ports and is, therefore, substantially at atmospheric pressure. In order that this expansion may not take place too rapidly, which would interfere with the scavenging of the burnt gases produced solely by the entrance of the fresh charge, the walls of the sleeve are given the shape shown more particularly in Fig. 2, and corresponding substantially to the expansion curve of the gaseous mixture after admission.

Fig. 4 represents a double-acting two-stroke engine. The piston A is extended on both sides by sleeves which, like the sleeves of the earlier examples, reciprocate around fixed pistons, and thus form two explosion chambers; the upper sleeve has inlet ports P arranged symmetrically in relation to the longitudinal axis of the engine, and exhaust ports O. The lower sleeve has also inlet ports P and exhaust ports Q arranged at 90°, in plan, to the ports of the other sleeve. The cylinder is provided at R and S with openings corresponding to the inlet ports, and at T and U with exhaust ports corresponding to the exhaust ports in the sleeves; these exhaust ports T and U communicate with an exhaust-conduit V. The carburetted mixture may be compressed either in a double-acting pump formed by a crown secured around the piston and reciprocating in a fixed cylinder, or as shown in Fig. 4 in two separate single-acting pumps formed by two external crowns W and X secured to the ends of the sleeves and reciprocating in the cylinder.

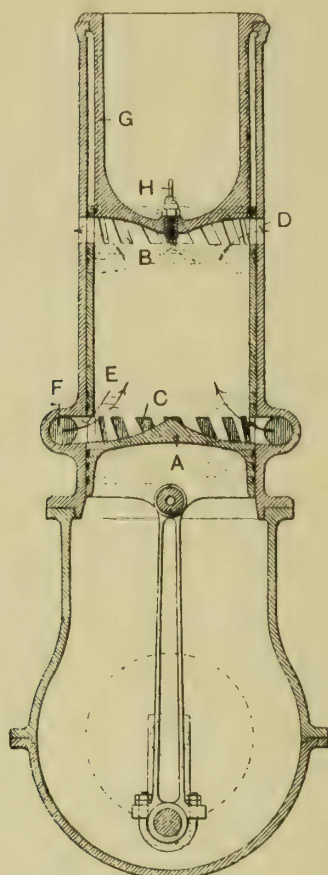


Fig. 1.

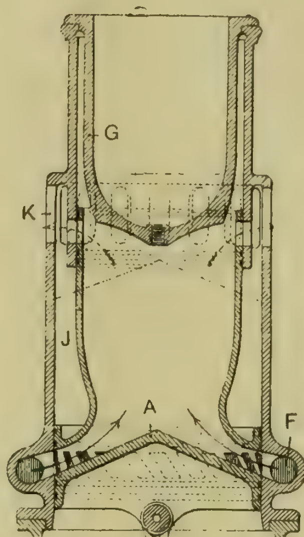


Fig. 2.

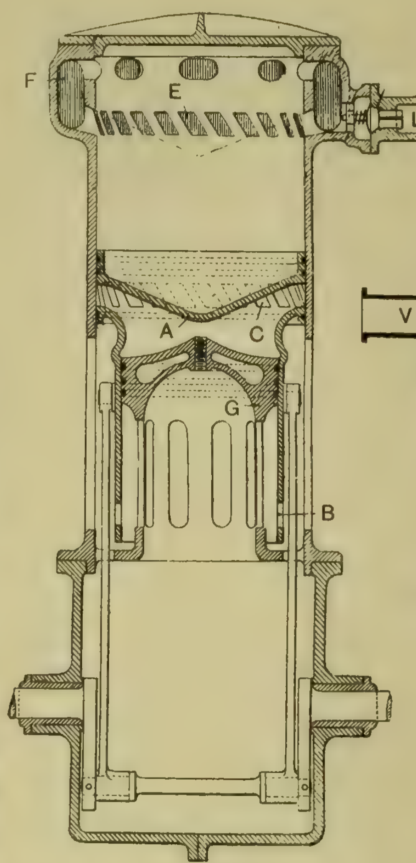


Fig. 3.

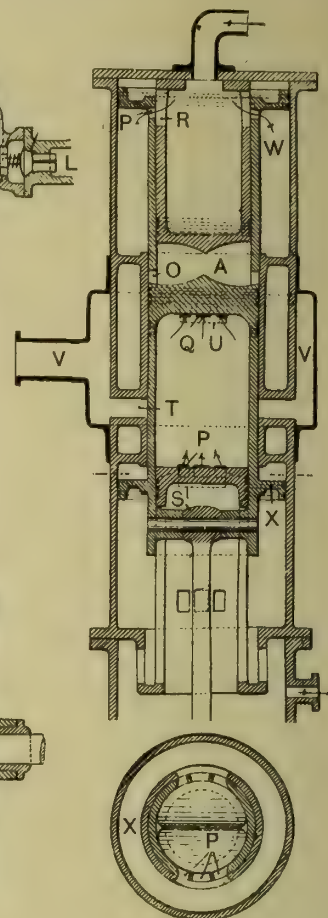


Fig. 4.

HARDY'S TWO-STROKE INTERNAL-COMBUSTION ENGINE.

Fuel Briquetting.—The subject of fuel briquetting is treated in a short pamphlet recently issued by the United States Geological Survey, Department of the Interior. Although some progress was made in the development of fuel briquetting in the United States during 1910 and 1911, this country still lags far behind several of the European countries, particularly Germany. In 1911 there were 21 plants in the United States which manufactured compressed fuel, an increase of five over 1909. Four of these plants were operated only for experimental purposes. Of those which operated on a commercial basis eight employed anthracite as the raw material, two used bituminous coal, two utilised semi-anthracite, one employed refuse from oil-gas works, one utilised peat, and three used mixed materials. The production of briquettes in the United States during the year 1911 was 218,443 short tons, having a value of £162,000.

Carburetter Experiments.—What promises to be an investigation of more than usual interest and utility is being conducted by the State Engineering Experiment Station at the Pennsylvania State College under the direction of Prof. J. A. Moyer, of the mechanical engineering department. With the increase in the price of gasoline has come the demand for some cheaper fuel that will give as good results. Kerosene would meet the demands if a satisfactory carburetter can be designed, and it is with a view of determining the merits and defects of various types of carburetters that the investigation is being carried on.

AIR COMPRESSORS.*

BY GEORGE BARR.

THIS paper is offered with the idea of giving some consideration to the reason why compressed air is accepted as an inefficient means of power transmission, and at the same time to take the opportunity of showing what has been done by manufacturers in the way of betterment without, it should be noted, any considerable pressure being brought to bear on the matter by users. Anyone who is interested in this subject and who has had experience of air compressors as they are to be found at work in this country at the moment, will be able to recall large numbers of machines where nothing but inefficiency can be expected, and as a great many of these machines range in age from, say, 20—30 years, then, to be just, we should, when looking into the question of efficiency, leave such plant outside our consideration, for it is in reality these old-time machines which have given compressed air the bad name from which it suffers at the moment.

It might, therefore, be well to consider the design of such old-type machines as against present-day plant, trying, if possible, when so doing, to show to what extent betterment had been obtained. Taking some of the oldest as an example we find in steam-driven machines the horizontal design was used, steam cylinders tandem to the air cylinders, air cylinders with no water jackets, spray cooling arrangement, piston speeds about 200—300, air valves, heavy flat type or rubber, clearance spaces anything, and single stage.

Present-day designs, mostly vertical, enclosed, forced lubrication, water-jacketed cylinders, generally two stage, for pressures from 70lbs. to 100lbs., cover in a general way the major portion of compressed air plant with piston speed up to 500ft. or 600ft. per minute, valve gear of combined, mechanical, and automatic type, or of light multiple ported small lift type, clearance spaces down to 2 or 3 per cent.; and when, in some instances, old compressors of the first-mentioned design, or somewhat similar, are discarded and new plant of present-day design installed, the results obtained easily explain the reason why compressors have for long been considered inefficient and rightly so. To demonstrate what can be done by installing new machines one case might be instanced where a compressor of four times the capacity of the old machine taken out required only the same amount of steam per hour, and if we examine results as obtained with electrically-driven units, which generally speaking have only become common within the last six years, it will also be found that in this very short period great steps have been made towards improvement, and examples can be seen where the efficiency of sets of similar capacity, working under the same conditions, have been improved by 20 per cent. It is, therefore, very evident that even with the little attention which has been extended to this class of plant, greater improvements are possible than can be made with any other plant generating power for transmission.

When considering the general question of compressed air efficiency we must not only examine the compressor, but go further, taking note of pipe lines, plant consuming the air, &c.; in this direction there has also been great improvement, and yet notwithstanding there is not the least doubt that very inefficient plants exist, and exist in very large numbers, and are still being laid down. Why is this? Is it simply because it is thought nothing but inefficiency can be expected? Why not have the same strict specification applicable to air compressing plant as has been the rule for electric generating plant? The only reason which can be put forward why such a course is not adopted would seem to be, taking a wide view of the matter, that few engineers have given much study to compressed air, and have taken it for granted that what has been must still continue. We might look at the matter from this standpoint and see if the facts are as indicated. What do we find in enquiries issued for large compressors: capacity of machine is given, if steam driven, steam pressure and vacuum mentioned, if electrically driven, voltage. It might be, but it is not general, that steam consumption is asked, and on a very rare occasion a capacity test is called for. Such a test when made is seldom, if ever, any check on the output of the machine: the test generally being to fill a reservoir of given capacity from atmospheric pressure to final working pressure: temperature of the air may be taken or may not, and when taken is generally misleading, and possibly allows of error up to 10 per cent. In fact, it is questionable whether there is at the moment one compressor at work, the actual capacity of which is known correctly through a test.

To give an instance of what is actually done in the way of testing even up-to-date plant we might take machines electrically driven, part of a large scheme of improvements in an installation where it is expected what is purchased would be proved before being accepted, and where it is to be clearly understood a test was called for in the original enquiry as issued, together with such information as amount of current consumed, size of air cylinders, stroke, revolutions, &c. Air receivers of a known capacity were used to measure the air as discharged, test made by filling receivers from atmospheric pressure to final working pressure, note taken of revolutions required for this, temperature of air inlet, and receiver temperature also taken—result, machines passed test easily. However, it might be pointed out, first, that the volumetric efficiency of a compressor varies considerably between atmospheric pressure and working pressure, and the above test, therefore, in the first place, ought to have been made with the machine discharging against working pressure during the whole run, not from atmosphere to working pressure as was the case. Further, under such test as was carried out no note was made of the fact that the receivers were already filled with one volume of air, which makes for even a greater error than the first-mentioned point. There is no intention of suggesting that these simple points are not known to engineers, but, on the other hand, such a test as described was all that was called for, and it will be only too evident that the results obtained are in a sense worse than no test, as they are entirely misleading. In fact, to consider even these two points it is quite within possibility that the error due to the reading being taken from atmosphere to the working pressure was anything, say, between 5 and 10 per cent., and that due to no notice being taken of the receivers already filled with air at atmospheric pressure, which with the final pressure as 100lbs. per square inch would equal about 12·8 per cent. Thus, roughly, the machines, even if they on test as carried out gave, say, a 5 per cent. higher result than called for, were at the very least 12·8 per cent. short in output; or, in other words, they were really smaller compressors than ordered, by this amount, and with possible 10 per cent. temperature error gives, say, 22·8 per cent. shortage.

When on this question it might be well to consider what might be termed a reasonable test, such, at anyrate, as would make certain of results, say, within 5 per cent., this 5 per cent. being margin for error in readings of, say, speed, temperature, pressure gauge readings, &c., which in a general way will be found as near as the average arrangements will allow of obtaining.

We might first decide on what side, *i.e.*, on the inlet or on the discharge, the test should be carried out, and to decide on this point all we wish to know is on which side is there likely to be the greatest chance of error. If the discharge be chosen, then we have first to arrange for reasonably large receiver capacity to make certain any small error in taking revolutions, say, of a high-speed machine, will be a very small percentage if spread over a reasonable time. Temperature of air entering machine should also be noted, as well as barometer reading taken during time of test. Machine should discharge during the test against full working pressure, average receiver temperature must also be taken into account, with the usual readings as to time and revolutions to fill the known volume of air reservoir, pipes, &c. Receiver and pipes should be drained of all water which may have collected and which might be anything. A still test is required after the running test to note drop of pressure due to leakage, temperatures must also be noted during such still test and recognition made of the fact that receiver volume being filled to final pressure has already one volume of air at atmospheric pressure.

These points might be taken as representing in a general way what is wanted for the test on the discharge side, although even with such there are still a few points which might be added; but it will be granted there is room for some considerable error on such method of test. Whereas, if a test could be made by simply measuring the air which actually passes into the cylinders we might come closer to a correct

* Paper read before the Manchester Asociation of Engineers, November 9th, 1912.

result, as taking the machine being dealt with as a two-stage compressor with, say, double-acting cylinders, then any air which actually passes into the low-pressure cylinder must be discharged, with the sole exception of the little leakage past the piston rod glands to atmosphere.

This second method of test, therefore, would seem the simplest, but will be found in practice difficult to carry out, as to measure air at atmospheric pressure passing through any known orifice requires, say, a small anemometer situated in a duct with readings taken at various points in the area. Special care is wanted to make certain that the duct is sufficiently long, and that no side draughts cause eddying, and no form of duct is suitable which might lead to any increase in the density of the air. On anything like a large compressor this last is certainly the most likely method to give closest results, but, on the other hand, is useless for machines of small capacities. If it were possible, therefore, to have a similar measuring apparatus fitted to the discharge side where greater speeds are being dealt with we could cover for all conditions, and be able to test large and small machines within reasonable limits of error. It is possible to obtain various types of instruments or meters for registering the quantities of steam, air, or gas passing through given sizes of pipes, and some of these are guaranteed correct within 2 per cent., but the cost generally runs to, say, £50, which is out of place in the way of expenditure to satisfy any user that plant purchased is in accordance with specification. There has, however, lately been patented a form of measuring apparatus which, although not giving a continuous reading, can, when fitted with a valve, enable a reading to be taken at any given moment as to the amount of air or gas passing the valve. This can be one of the valves in the system, say that on the discharge side of the main air receiver, and the only extra cost is this special fitting. Having such, which can be had guaranteed correct within 2½ per cent., then with a thermometer taking the temperature of air passing this point as compared with temperature of air at inlet to compressor, we have full data necessary.

There is little doubt if a test be made with this last-mentioned arrangement on all machines at the moment running, the shortage in output would be surprising, and, going further and making a check on the horse-power required to compress, say, every 100 cub. ft. free air up to the final pressure, considerable difference would be found. The actual proof that any given machine is really delivering the full amount of air specified is not, of course, sufficient to prove the machine the best possible, as some designs may require considerable power to compress the air, due to small restricted air passages, poor cooling arrangements, low mechanical efficiency, &c.; on the other hand, a machine may show good results in all these points, but might not have a long life at such high state of efficiency. After all, what the user wants is a machine to show small horse-power for air actually delivered, and a figure representing horse-power to compress, say, every 100 cub. ft. of air, covers volumetric efficiency, mechanical efficiency, losses in compression, &c., and taking the present types on the market it will be found that a figure such as 20·5 electrical horse-power is required to compress and deliver every 100 cub. ft. of air up to 100lbs. pressure. Such a figure might reasonably be expected, as covers for, say, 90 per cent. motor efficiency, 90 per cent. mechanical efficiency, and 80 per cent. compression efficiency; this, with a reciprocating two-stage air compressor, or for steam-driven machines the indicated horse-power in steam cylinders per 100 cub. ft. of air compressed as above should be about 20.

The steam-driven compressor is certainly the machine to install if a choice can be had and efficiency is the main point at issue, as here we have no steps and their accompanying losses as with the motor-driven plants, where, granting for simplicity the steam-driven compressor has the same mechanical efficiency as a generating set, then we cut out, say, roughly, 10 per cent. dynamo loss, possible 2½ to 5 per cent. loss in transmission, and the further 10 per cent. loss of the driving motor. These figures may be questioned, say, between 1 or 2 per cent., but as we are working with a difference of roughly 20 per cent. the matter is quite evident, and should receive attention when new efficiency plant is being installed.

Passing from this side of the subject to that of the present designs, and bearing in mind the present tendency to install more of such plants in collieries, shipyards, &c., it might not be out of place to give an idea of the general tendencies. First, we find in a general way that colliery units range from about 1,000—5,000 cub. ft., with the electrically-driven units ranging from 1,000—3,000, or with unit horse-powers from, say, 200—600. These represent plants as placed on the bank and power drawn from local power companies' mains, but in some quarters there seems to be a tendency to try smaller in-bye semi-portable sets of strong and efficient design, with more attention given to strength and simplicity than was hitherto the case, when lightness was considered the main necessity.

There is, it will be noted, something to be said in favour of these smaller electrically-driven sets if the design is substantial, as where power is being taken from a power company, and possibly cables already exist, such machines set down in the intake mean small outlay and a change can readily be made, say, from electrical coal cutters, pump and haulage gear to compressed air machines. The compressors are usually set down temporary, as close to the working face as possible, and the foundations being practically nothing, little trouble is had in six or 12 months in moving forward again towards the face.

Taking a comparison in through efficiency between the above electrical methods as against a large steam-driven compressor on the bank, we have, say, the following losses: first, in the steam-driven machine, mechanical loss 10 per cent., transmission losses including leakage 7 per cent. For the electrical plant we must assume the current generated at the power house, as it will be found in a general way that the losses in the generating will equal the extra charge for the power as made by the power company. Then we have 10 per cent. mechanical loss in engine, 10 per cent. loss in dynamo, 5 per cent. loss in transmission for the small in-bye machines; further, 10 per cent. loss in motor driving compressor, and for large motor-driven machines we must make the same allowance of 7 per cent. loss for air transmission as in the steam-driven sets, and for the small in-bye sets we may have, say, further loss of 3 per cent. for the short air piping and leakage. These figures are all relative, but are a fair and reasonable mean for all the cases. Steam losses therefore equal 17 per cent., large motor sets 37 per cent., small motor sets 38 per cent., or a difference of 20 and 21 per cent. respectively, representing the margin to cover extra price paid to power companies, or a figure which will readily enable it to be decided whether extra interest could not be readily paid on the extra capital for the steam-driven sets, together with the difference in running cost and upkeep of both schemes.

It might also be well when on this question to take into account the latest arrangements, viz., exhaust steam or mixed steam turbo-compressors. A few of such machines are at the moment being installed, and it may seem out of place at this time to take these into consideration, but where some facts are already granted we may, at anyrate, look at these for comparisons. The facts seem to be that even the makers of turbo-compressors agree such machines cannot be made reasonably efficient in sizes under 2,500 cub. ft. capacity and pressure of over 60lbs. If this is granted by the makers then even the efficiency of the larger sets becomes doubtful. In fact, to look at the problem from a common-sense point of view, we know now from experience the difficulties that are experienced in securing reasonably efficient steam turbines where the steam is allowed to follow out its natural tendency, *i.e.*, expand. How much more difficult must it therefore be to force an unnatural condition and compress the air up to, say, 80lbs. or 100lbs.

Granted in the steam end of the exhaust steam turbo-compressing set savings are apparent, it would appear a better, and at anyrate, a sounder policy to gear drive a reciprocating machine of a known efficiency, with a loss in the gear drive also known and possibly not representing more than 2—3 per cent., than to drive a turbo-compressor which is, on the other hand, even by the makers accepted as inefficient. The turbo-compressor, however, is what is wanted for low pressures, such as blowers, where large capacities and little pressure are desired, and will certainly replace the large cumbersome vertical or horizontal types where mechanical efficiencies are very low, and can never hope to be much improved.

Having brought up the question of efficiency, testing, &c., it would also be well to look into the change, if any, which has

taken place in details of construction, such as cooling arrangement, governing, lubrication, valve gear, &c. Taking the governing arrangements first, and that as applied to steam-driven machines, we find in the oldest type simply a maximum speed governor fitted, throttling at the main steam stop valve to reduce supply to meet the demand, and for safety, a relief somewhere on the system, most likely in the air receiver. In other, and later machines, we find additional refinements such as automatic air control, actuated by receiver pressure at the same time as separate steam throttle valve is closed, reducing the speed of machine to a minimum when the pressure in the system rises, and automatically opening both steam valve and air inlet valve when pressure falls. This method of governing steam-driven machines is not as good as simply reducing the speed of the machine when the pressure rises above a predetermined limit, and with a variation of, say, 10lbs.—15lbs., the output of the machine can be reduced from full to one quarter, and no trouble through carbonising of oil or overheating is had, as is found to be the case where the inlet to air cylinders is simply closed and the machine runs on a partial vacuum. In fact, the gradual reduction of output with the reduction of speed plus a relief valve on the receiver, is very much better than the first arrangement.

There is, however a further and possibly better arrangement for steam-driven sets, but which has only been used in a very few sets, and is only possible where two or three crank machines are in use. With this arrangement the compressor is simply stopped when the final pressure is reached, and with, say, a drop of 10lbs. again starts up in a similar manner to the usual hydraulic pumps which operate in conjunction with the accumulators, care being taken to have large relief valves on cylinders and valve casings together with efficient draining on the main steam connections.

In electrically-driven machines, however, the methods of governing have been many and varied. First, we had the design where the air was simply by-passed from one end of cylinder to the other; this required considerable power when running light, with the additional objection that we always had a little extra clearance space due to the extra valve or ports involved. Then we had a second method for belt and electrically-driven sets, where we simply closed the air inlet and allowed the machine to run light. This method requires less power and is certainly more economical than the first, but it has the objection of causing heating troubles; with the vacuum we vaporise the oil, and no matter what oils we may use the result with a machine with such governing, if subjected to long runs on the governor, is seizure, breakages, &c. In some belt-driven sets automatic belt-shifting gear is fitted and acts fairly well, but as these are only small and in a sense become less as time passes, are only mentioned showing what is done in this direction.

We have a third system as applied to all classes of motor-driven units, *i.e.*, where the machine is always allowed to draw in the full capacity of air, but when the pressure in the system has risen to such a point that no further supply is wanted, then a by-pass valve on the discharge side opens and the machine simply discharges to atmosphere. In a machine of the two-stage type fitted with such governing gear, we find the amount of power required when on the governor to be practically the same as where we close the air inlet to the cylinders, and in constant-speed machines the light load will be 40—45 per cent. full load, this figure covering motor losses and representing two crank machines of reasonable mechanical efficiencies.

Should we go a step further with governing of constant-speed plant we find that with a combination of the above, that is, control automatically on both inlet and discharge, we have the light load figure reduced 16 per cent. to 20 per cent., which is about the bottom figure possible where constant-speed plant is adopted and where control gear of the absolute class is at work. But we can move in another direction, and in place of entirely closing the air inlet or opening the discharge to atmosphere, fit such an arrangement as the following, which has also great advantages. In this arrangement we draw in the air at every stroke, but as the pressure rises beyond a certain point we only compress a portion of this air and allow, say, the first portion of the compression stroke to escape back to atmosphere before any work has been done on same. Various methods are found to allow of the above, and when fully considered it will be found such gives good running, together with highest efficiency possible where constant-speed plant is in operation.

We can go further and adopt variable-speed motors, and thus cover for a considerable variation in output without having any fear of lubrication or heating troubles, but this is not generally wanted unless, say, for one unit in a large station, to make certain that the plant installed will be sufficiently elastic to cover the variation in load over, say, a year's time.

Apart from the foregoing, we find in electrically-driven sets the use of automatic starting and stopping gears, and certainly considerable savings can be shown; but unless fairly large receiver capacity is available to assist towards increasing the length of stoppages, it is found, sometimes, little saving is made through the peak load every time a start is made practically equalling the current saved when the stoppages are short and frequent. It is also to be borne in mind that fluctuations of about 10lbs. are usually wanted for stopping and starting gears, and in some plants this is not allowable. Finally, with a combination of automatically varying the speed of the motor and automatic stopping when the highest pressure is reached, we practically cover the controlling devices used; this last, however, has only been installed in a very few instances, and although certainly making for the best economy is not generally necessary.

Taking a summary of the above and at the same time giving close attention to what is really necessary, we find with a large installation of four machines of, say, 2,500 cub. ft. capacity each, first, no automatic stopping gear is wanted, as we would have an attendant who can be made use of for any starting or stopping actually wanted over a given day. But if we had in an electrically-driven plant one of the sets with a variable-speed motor to give a desired range when all the plant was in use, this would cover all actual requirements, but with the additional controlling gear arranged to allow so much air to be discharged before compression starts we should have a plant covering for all possible fluctuations, and assure for highest efficiency over any varying conditions, with the extra advantage of being reasonably cheap.

The valve gear in air compressors is also a part which has changed considerably, although it is only within recent years that efficiency was the aim of the alterations. Previously all alterations were due to the continuous breakages; even in the older designs when long-stroke slow-running compressors were those used, the valves gave considerable trouble, no doubt due to the excessive size and weight, little thought being given to the matter except in special instances when some of the larger makers moved towards mechanically-operated designs, or combined mechanical and automatic arrangements. This latter class of gear was possibly the first successful as used for the higher speed designs, and it may be taken it has been the increase in the speed of the machines which has made for the betterment in the valve gear designs.

At the moment automatic valve gears are those most used, and certainly it would appear that the greatest progress has been made in this class. The valves of this type take the form of a multiple-ported or grid valve with very small lift, the form of valve, fixings and springs being covered more or less by various patents, but apart from the design, the material and its treatment enter considerably into the success or failure. Should an examination be made of indicator cards as taken from one of the latest high-speed machines with multiple-ported valves it will be apparent the losses due to throttling either on the inlet or discharge are very small, and leave little margin for improvement in this direction. This type of light, small lift multiple-ported valve would at the moment seem that best suited to the high-speed type of machine, and can even be fitted with profit to existing low-speed compressors, enabling such class of plant to be speeded up, thereby increasing the output and also the through efficiency; in fact, such alterations have been carried out with success in quite a large number of compressors on the Rand.

The matter of cooling is also a point which has received considerable attention, and where it was common to install single-stage machines for pressures of, say, 60lbs., 80lbs., and even 100lbs., we now find two-stage compression most common. The cost of the installation has been considerably increased by so doing, owing to two lines of parts being wanted, together with the addition of the intercooler, but the

end has justified the means. First, there is no doubt that an increase in compressor efficiency of, say, 10 to 15 per cent., is obtained in large-size units, which also makes for greater reliability due to absence of heating troubles; and, further, we can secure cooler and drier air in the system, but it is necessary to have intercoolers of reasonable size, and for even this country one square foot cooling surface for every 4 cub. ft. air compressed to 100lbs. is not too large. The intercoolers are also better if placed outside the engine rooms in the atmosphere, say, on the shaded side of the building; the cylinder cooling in the best make machines we may take as generally the most efficient possible, as most compressors now have the jackets carried entirely round the cylinders and covers; although instances are still found where the jacket is simply a box cast round the cylinder barrel, open on top and filled periodically when evaporation has necessitated this, or as previously mentioned, we can even find old-time horizontal machines at work where a spray is still used in the cylinders, no water jacket but a separator fitted to get rid of the water, not that the spray is not an efficient means of cooling, but the effect on the cylinder barrel piston and rings is such as calls for constant renewal.

When on this matter of cooling we might at the same time take note of a question often brought up by an intending buyer, that is re-heating. Now admitted re-heating would certainly add considerably to the efficiency of a compressed air installation, but if we take the general use to which air is put in this country, we find only a very few instances where it is possible to re-heat. In collieries, shipyards, &c., the air is used not at one particular spot, but possibly one hundred, and to heat the air, say, immediately it leaves the compressor, to a matter of 350° Fah. and then pass same along a matter of 1,000ft. piping is simply wasting money. Neither is it worth considering re-heating at all the points of use unless these are few and at each large quantities of air are wanted. If such a condition as the last is possible then we could show a saving of roughly 25 per cent. in air consumption with very little cost for fuel. However, it will be found best to cool and dry the air before use for general conditions, and the simplest and cheapest manner to get this done will be to arrange the air receivers a fair distance from the compressor, allowing the air to cool in its passage to the receiver where the moisture can be collected and drained off, assuring cool and dry air to pass into the pipe system. In some very large installations, however, we find aftercoolers in use fitted between the compressors and receivers; thus, in this country, where considerable moisture is held in suspension in the atmosphere, we can still collect the greater proportion of same in the receivers, and have dry air supplied to the various tools or motors, saving greatly in the upkeep of hose connections and plant in general.

With regard to the question of lubrication in a general way, taking it for granted that with the enclosed type of machines, the forced system is that used (but this only applies to main bearings, connecting rod and such parts as do not come in contact with the air when being compressed); but with the newer designs of machines where piston speeds are higher, we want more care taken of air cylinder lubrication. In fact, more trouble develops from the use of unsuitable oils in the cylinders than is necessary. In the first place, we must note we do not have the same conditions prevailing in an air cylinder as in the average steam cylinder, where we can always rely on condensation assisting towards lubrication arrangements. In the air cylinders, although we have moisture in the air, this will not deposit at the high temperatures, in fact, the air cylinders will run very dry, and seizures be the rule if proper care is not taken. In some instances, plenty of oil is given, sometimes too much, but the oils used may leave heavy carbon deposits, in time choking valve ports and passages, first result considerably more power consumed than necessary, finally damage and stoppages. We, therefore, want an oil for air cylinder lubrication with high flash point and which will leave little or no deposit, such oil as, say, high-class gas engine oil being found best.

These remarks do not refer to compressors other than the usual machines for pneumatic tools and other similar pressures. For higher pressures machines of three and four stage are necessary, say, up to 3,000lbs. Finally, air compressors can now be had very much higher in efficiency than, say, ten years ago. More care is also being taken in the layout of pipe systems, &c., and if this betterment was carried into the plant which consumed the air, there would, without doubt, be shown in such instances as collieries, &c., results equal to the best electrical schemes. This statement does not suggest that over an instantaneous reading a through efficiency could be shown with air equal to electricity, but taking a year's comparison with all upkeep charges, running cost, interest of difference in invested capital, or, in other words, the cost per ton of coal raised averaged over a year, this being the correct test, and the efficiency, which really matters.

PATENTS AND INVENTIONS.

At the opening meeting of the new session of the Birmingham section of the Institution of Electrical Engineers, Mr. A. M. Taylor, the chairman, in his address, dealt with the subject of patents and inventions. The prosperity of the country in general, and of the electrical industry in particular, depended, he said, to a greater extent upon new inventions than perhaps was usually supposed. A country which did not provide new developments in industry was apt to stagnate, and would certainly be unable to compete with other countries which were providing these developments. The "commercial element" of the country might arrange for the manufacture of standard apparatus on a vast scale, and so reduce costs; but unless it was at the same time ready to seize upon the first clear step in advance in the way of producing new and useful results, or equal results by a new process at lower costs, all its commercial organisation would have been in vain. The question then arose whether it was not desirable in the interests of the country at large to give still greater stimulus to invention; as there was the obvious temptation for large concerns having abundance of capital, and control of certain markets, to seek to use this capital to enhance their profits and to stifle competition from any new developments. For example, a concern having large capital at its back could afford to keep paid agents continually on the look-out for patent developments in the same, or in contiguous, directions to those which it owned, and could afford to buy up the patent rights (very often for a mere trifle, if in the hands of individuals), solely with the object of stifling any competition that might otherwise have been set up against their own standardised articles. Such a course, which had, the author understood, been carried on to an extreme in the United States, resulted in the establishment of huge monopolies, and could not be altogether in the nation's interests, besides being quite counter to the objects with which the patent system was instituted.

The original object of the granting of patents was, he observed, to encourage the making public of new ways and means of effecting given results, with a view to the general prosperity of the nation as a whole rather than that of the inventor; but, at the same time, to make it thoroughly worth the inventor's while to trust to a reasonable reward guaranteed by the Government rather than to the risky possibility of his making a fortune out of some process of which he could only reap the benefit by keeping it an absolute secret. Unfortunately, as the law now stood, there was almost as much risk of financial loss in patenting or making public an invention as in endeavouring to keep the invention a secret.

One very important reason for the apathy of the capitalist, or the manufacturer, towards the inventor, was to be found in the fact that there was a profound distrust in the value of patents. It was, perhaps, not generally known by the inventor that, even when he had survived the scrutiny of the British Patent Office, he had only secured a reasonable chance of his invention not having been anticipated at the Patent Office, and he had no guarantee whatever that interested persons might not be able to show that the invention had previously been tried in practice in a semi-public way, even though no application for a patent might have been lodged. Neither had he any assurance that the invention would act in the manner predicted, for, on this point, the British Patent Office took no responsibility. Neither had he any assurance that there was real "subject matter" in his invention. The result being that, directly he got his invention started and working successfully, it might be combated by interested parties in the Law Courts,

and if it could not be shown to contain "subject matter" it was disallowed. The knowledge, in a general way, that there were difficulties of this sort to contend with had no doubt had its influence on the capitalist, and even on manufacturing firms who would otherwise have dealt with the matter. A question, then, for careful consideration was whether the inventor got sufficient encouragement from the State to compensate him for these uncertainties, and whether these things were not done better in other countries. In the United States of America they were much more careful in accepting a patent than in this country; but it was in Germany especially where the investigation of a patent was carried out with a thoroughness that left the inventor, when he emerged successfully through the ordeal, with the confidence that, even if he were attacked in the Law Courts, his patent would almost certainly not be cancelled, either on the ground of lack of "subject matter" or on that of inability to work, if made as described in the specification. Another very good feature about the German patent was that the only fee which the inventor had to pay to obtain this excellent benefit was a matter of some 20 marks (approximately £1), since he did not have to pay the remaining 30 marks unless he was granted the patent, which might be as much as two years later. The question of the "validity" of a patent, or otherwise, was one of such vital importance to the inventor, and the difference between what constituted sufficient to obtain (in England) the grant of a patent and what constituted "subject matter" was little understood by the average engineer.

The author took as an example the Ilgner case. Here was a patent which had been granted in this country, and in the pushing of which large sums of money had been incurred, and which, at the instance of a competitor, who had no master-patent to offer in its place, was declared to be invalid. The Law Courts held that the employment of a motor generator between the prime motor and the final motor was, in essence, the Ward-Leonard idea; that the essential idea of the Ilgner invention was the putting of a flywheel on the motor of the said motor generator; that it was obvious to any competent engineer that a flywheel was necessary, in view of the nature of the load; that the difficulty of using a flywheel in connection with reversible loads was got over by combining it with the Ward-Leonard system; and lastly, that no act of invention was performed in arranging that the motor of the motor generator should slow up with an increased load, as this was an obvious necessity if the flywheel was to perform its proper function. The judgment in this case showed very clearly the erroneousness of the common idea that any combination of known ideas which effects a new or improved result was subject matter for a patent.

What, then, could be done for the inventor? Undoubtedly the right way was for the British Patent Office to be invested with powers to enable them to determine authoritatively whether an invention possessed "subject matter" before they issued letters patent. It seemed to the author that the British inventor had for too long neglected to avail himself of the means of combination possessed by other individuals, and some powerful organisation was needed in this country to defend his interests and to state his case in Parliament, &c. Such an institution had, he understood, recently been formed.

It was, he believed, fairly common practice for large electrical manufacturing firms to call upon their employés to sign a document, whereby they agreed to hand over absolutely to the firm all inventions they might make while in their service, and disclaiming any right whatever to participation in the profits. The theory of this arbitrary proceeding was that the employé had got his knowledge through his employer. In the large majority of cases, however, the employé came to the employer with knowledge gained elsewhere, and to the benefit of which the employer was not entitled. No doubt there were many simple ideas which were the result of a happy inspiration in the course of one's daily work; but the day had gone by when anything of real value could be evolved in electrical engineering without an immense amount of brain work; and, if there was not sufficient stimulus of reward, the busy engineer could hardly be expected to spend his evenings at such problems. There were, in his opinion, certain improvements which might be made in the present relations between employer and employé which were fairly obvious. It should be absolutely illegal for an employer to compel an employé to hand over to him his invention, on pain either of dismissal or of prejudice in any way to his advancement if he stayed on with the firm employing him. The employé should certainly be allowed to apply direct to the Patent Office in the first instance, if he chose to do so. In all these matters an Institute of Inventors might be of inestimable service to the inventor, if properly arranged to safeguard his interests.

Undoubtedly the engineer with a genuine bent for invention needed every encouragement. Could not our Institution do something in this sense? All their premiums appeared to be granted on the merits of papers read before the Institution, judged on the basis of their contribution to the general fund of knowledge, or their promotion of a good discussion. But if they had a substantial premium set aside for the inventor who might read a paper descriptive of his work (even if the object of that work be not finally attained), such premium might help him to continue his experiments or developments. And, if contributions towards such a fund were invited on the part of members generally, would there not, probably, be a large response from members, and thus an additional stimulus given to original work?

The period of six months allowed between the lodging of the provisional and that of the "complete" specification was, he thought, altogether too short for inventions that involved a great deal of investigation, calculation, experiment, and development. As a partial remedy he suggested that the inventor should be allowed, under increasing penalty, to extend the time to nine months, or even a year. It was not perhaps general knowledge that the British Office gave, before the lodging of the "complete" specification, something in some measure corresponding with the "patents of addition" which it allowed after the lodging of that specification. He referred to the embodiment of two or more "provisional" specifications in one "complete" specification, under the rule relating to "cognate" applications. Suppose, for example, that during the six months succeeding the lodging of the "provisional" one found several directions in which difficulties had to be overcome, requiring supplementary inventions, and lodged these ideas in the form of "provisionals," then, when the six months was completed, all these could, with the consent of the Patent Office, be embodied in the one complete application. Thus, in any question of priority, one would be allowed the date of the lodgment of any one of the provisionals as the date of that particular stage of the invention.

A suggestion might also be made as to whether the British patent law should not differentiate between "inventions" in which there was held to be "subject matter" and those in which there was not. There was a large class of very useful inventions in which two or more independent ideas were combined to produce a new and improved result. Surely such an invention deserved better of the public than to be put upon the scrap-heap after a lot of time and money had been spent upon it? Take, for instance, the Ilgner case; it was very easy for a judge to be persuaded by expert witnesses that the thing was self-obvious, but the ordinary engineer might be allowed to have his doubts about this. In any case, the fact remained that the crushing of a patent in this way was a distinct discouragement to invention, and that the best class of inventor, viz., the well-informed, plodding engineer, who had a definite purpose and the best equipment for effecting it, was the one who was the most hard hit by it. He suggested that complete protection be granted to this class of patent, but only, however, for a limited term of years—say 10 years instead of 14 years. This would mitigate the discouragement to invention which was otherwise put upon the best class of inventor. Anything which discouraged inventions that would confer a boon upon the country producing them (though they need not be in themselves of striking novelty) was actually a blow aimed at the trade of the country itself, and therefore should be remedied with the least possible delay.

INDUSTRIAL AND TRADE NOTES.

More Diesel Ships.—We learn that amongst several North Atlantic cargo vessels which have been ordered recently are three Atlantic transport liners, which are to have Diesel oil engines. The builders are Messrs. Harland & Wolff.

Exhibition of Auto-cars and Motor Machinery at Brussels, 1913.—An exhibition of auto-cars and motor machinery is announced to be held at Brussels next year under the auspices of "La chambre Syndicale de l'automobile et du Cycle de la Belgique." The exhibition will be held from January 11th to January 22nd, 1913.

Regulations for Trials of Petrol Lorries.—The War Office has issued regulations for the trials of petrol lorries to qualify as the type of vehicles suitable for earning the War Department subsidies. Two types of vehicles are required to carry loads of 4 tons 10 cwt. and 2 tons 15 cwt. respectively, and they must be ready for trial on February 3rd next.

The New Dock at North Shields.—The new dock at North Shields, constructed for Messrs. Smiths Dock Company, Ltd., is nearing completion, and will be formally opened towards the end of the present month. The dock is specially fitted for expeditiously dealing with the largest oil tankers afloat, and is equipped with powerful pumping installations and other appliances.

German Pig-iron Production.—The production of pig iron in Germany during the first ten months of the present year amounted to 14,148,638 metric tons, as compared with 12,842,690 metric tons during the corresponding period of 1911. The output during last month amounted to 1,589,262 metric tons, being 109,977 metric tons more than in September. These figures constitute a record in the pig-iron production of Germany.

Order for Marine Oil Engines.—Scotts' Shipbuilding and Engineering Company, Greenock, have received an order from the British Admiralty for the construction of the engines of the oil-tank vessel which is to be built at Chatham Dockyard. The machinery will consist of two sets of internal-combustion engines of the F.I.A.T. type, of which Scotts' Company are the licensees in this country. The Admiralty have also placed with the Fairfield Shipbuilding and Engineering Company, Govan, an order for a set of oil engines for the oil-tank vessel which is being built at Devonport Dockyard. These engines, which will be of the Nurnberg-Diesel type, will be the first of the kind constructed by the firm.

Steel Prices Advanced.—The Scotch steelmakers on Tuesday last resolved to advance prices 5s. per ton all round, making boiler plates £9. 2s. 6d. per ton, ship plates £8. 7s. 6d., angles £8, and bars £9, all less 5 per cent. for Clyde delivery, or equal. The advance was anticipated, and makers have booked fair business at the previous prices within the last few days. A similar decision was come to on the same day by the North of England steel manufacturers.

Re-opening of the Clyde Bridge Steel Works.—The Clyde Bridge Steel Works, which have been shut down for five years, were last week re-opened owing to the unparalleled demand for steel in the West of Scotland. These works have nine smelting furnaces of comparatively modern type, and three rolling mills suited for the manufacture of ship and boiler plates, and when in full operation find employment for about 900 men. The works are situated in the neighbourhood of Glasgow, and enjoy first-class railway and shipping facilities.

Weighing Machines for Coal Trains.—To prevent delays in dealing with the coal traffic for shipment from Immingham three weigh-bridges have recently been put down on the sidings adjoining the dockside coal hoists. They are described as 30-ton automatic weigh-bridges, capable of weighing anything from 28lbs. up to 30 tons, though they were tested at the makers' works up to 75 tons. Their special value is to weigh trains of coal wagons in motion. As a train-load of coal passes over the bridge at the rate of two miles an hour the machine accurately checks and weighs every truck with its load.

The Manufacture of Tinplates.—A Report has been recently issued from the Home Office by Dr. E. L. Collis, one of H.M. Medical Inspectors of Factories, and Mr. J. Hilditch, one of H.M. Inspectors of Factories, giving the results of a special enquiry which they have made into the effect of the conditions of work in the tinplate industry on the health of the workers engaged therein. The Report indicates that the health of persons engaged in the tinning and finishing of plates is injuriously affected by the fumes and dust to which they are exposed in these processes, and makes recommendations with a view to requiring the adoption of precautionary measures.

German Machinery Industry.—A report has just been issued on the development of the German machinery industry in 1911 (excluding foundries, makers of railway material, rolling stock, and the like), as evidenced by the working of 261 joint stock companies possessing an aggregate nominal share capital of 32 millions sterling. The dividends worked out at 5·3 per cent. in 1911, as contrasted with 5·6 per cent. in 1910, and 5·9 per cent. in 1909. Of the above-mentioned nominal share capital for 1911, no dividend was received by £5,100,000; £3,200,000 received 4 per cent.; £1,500,000, 5 per cent.; £3,600,000, 6 per cent.; £950,000, 7 per cent.; £4,800,000, 8 per cent.; £2,200,000, 9 per cent.; and £2,300,000, 10 per cent. dividend.

Coal Production in India.—The total quantity of coal mined in India during 1911, according to a report issued by the Calcutta Commercial Intelligence Department, was 12,715,534 tons, as compared with 12,047,413 tons in 1910. Of the 1911 production 4,223,000 tons were used on Indian railways. Very little is imported, the figures for the past year amounting to only 318,669 tons, of which 245,043 tons were supplied by the United Kingdom. Bengal is by far the greatest producer of coal in India, the Jharia field producing 50·1 per cent. and the Raniganj field 33·9 per cent. of the total for all India. It is difficult to say exactly how much coal is used annually in India for domestic consumption, but the amount can only be comparatively small. The spread of the use of coal for domestic purposes is mainly hindered by the absence of a cheap and suitable stove.

Forthcoming Mining Exhibition in London.—An exhibition of mining machinery is to be held next year in the Royal Agricultural Hall, Islington, N., from May 29th to June 7th. An Association of manufacturers representing leading firms in the industry has been formed. These exhibitions have now become quinquennial, so that after next year there will not be another till 1918. Three fourths of the space is already taken up, and a strong consultative committee has been formed to supervise different sections of the exhibits and to organise lectures, &c. The committee consists of Mr. W. E. Garforth, LL.D. (President of the Institution of Mining Engineers), Sir Ralph Ashton, Prof. J. S. Haldane, F.R.S.; Sir Henry Hall, I.S.O.; Sir Thomas H. Holland, K.C.I.E., F.R.S.; Mr. A. M. Lamb, M.Inst.M.E.; Mr. H. C. Peake, Past President Inst. M.E.; and Mr. H. L. Sulman, Past President I.M.M. Various lectures have already been promised. The offices of the Exhibition are at 43, Essex Street, Strand, London, W.C.

Motor Vehicles in Russia.—The Journal of the Russo-British Chamber of Commerce at St. Petersburg states that the manner in which the popularity of the motor-car has grown in Russia within the last few years could hardly have been foreseen, for there seemed to be serious obstacles which would be likely to impede their general acceptance in the near future. In spite of these impediments, however, much has been done to popularise motor cars through exhibitions and trial races, with the result that the value of the imports of motor-cars and motor-cycles has increased tenfold since 1906, and has all but tripled in the last two years. During this latter period taxi-cabs have become general in St. Petersburg and other towns. Imports from the United Kingdom constitute but a small portion of the total. The latest detailed figures available are for 1910, in which year the imports of motor vehicles from Germany were: 881 cars with four seats and more, 181 cars with less than 4 seats, 185 lorries and chassis, and 652 motor cycles. The "Journal" adds that energetic measures should be taken at once if British-built cars are to secure an adequate share in the possibilities which are offered them by the Russian market.

The Boilermakers' Society.—The results of the voting on the policy of the association with regard to the special advance of 4 per cent. on piecework rates—which was asked some time ago and refused by the employers—is given in the November report of the Boilermakers' Society. The ballot shows 4,316 for and 1,914 against giving one month's notice to cease piecework in shipyards, and 1,529 for and 2,361 against giving one month's notice to cease work altogether in the federated shipyards in order to enforce the special advance of 4 per cent. on riveting rates, giving holders-up 10½d. to the riveters' 1s. Votes are, it is stated in the report, being taken at the November branch meetings on the following resolution, which was carried at the national conference held at Newcastle in September: "That we favour a national agreement between the Shipbuilding Employers' Federation and the United Society of Boilermakers and Iron and Steel Shipbuilders for dealing with general fluctuations of wages and questions of an agreed general character, or such as may be remitted from local conferences with the consent of both parties at local conference. All local questions to be dealt with locally and finally in localities. There shall be a neutral chairman at all local conferences."

Employment in the Engineering Trades.—According to the Board of Trade report on the state of the labour market, employment in October continued good. It was better than a year ago, and slightly better than last month. There was an improvement in the iron and steel, engineering, and shipbuilding trades.. The

upward movement in wages continued. Compared with a year ago all the principal industries showed an improvement, which was most marked in the pig iron, iron and steel, engineering, and tinplate trades. In the 383 trade unions, with a net membership of 885,100, making returns, 17,822 (or 2 per cent.) were returned as unemployed at the end of October, 1912, compared with 2·1 per cent. at the end of September, 1912, and 2·8 per cent. at the end of October, 1911. The changes in wages taking effect in October affected 525,000 workpeople, and resulted in a net increase of nearly £25,000 per week. The number of disputes beginning in October was 72, and the total number of workpeople involved in all disputes in progress during the month was 36,312, as compared with 27,918 in September, 1912, and 58,528 in October, 1911. The estimated number of working days lost by disputes during the month was 301,000, as compared with 284,000 in the previous month and 444,600 in the corresponding month of last year.

Wages in 1911.—The Comptroller-General of the Labour Department of the Board of Trade (Mr. G. H. Barnes) has issued his report on changes in rates of wages and hours of labour in 1911. It states that the outstanding feature of the year was an increase in wages to the transport group of trades. The aggregate increase in the wages bill of these trades greatly outweighs the net advance in all other industries, which amounted to about £18,500 per week, spread over the 800,000 workpeople affected. The upward movement in the non-transport trades continued throughout 1911, and has become more rapid during recent months. The report states that at the end of 1911 the general level of wages was higher than at the end of any year since 1893, except 1907 and 1908. The number of workpeople who received increases was 507,207, and the amount totalled £56,247 per week, while 399,362 sustained decreases amounting to £11,669 per week. In the coal-mining industry the changes in wages taking effect in 1911 resulted in a net decrease of £9,553 per week in the wages of 390,793 workpeople. In engineering trades there was a net increase of £8,476 per week in the wages of 142,140 workpeople. In the shipbuilding trades 67,344 workpeople received a net increase of £7,346 per week.

Iron Ore Supplies.—Interesting information regarding the supply of iron ore, and the desire of British manufacturers to find fresh sources, was given before the Dominions Royal Commission which is enquiring into the trade relations of the Empire and the development of its resources. Mr. Wallace Thorneycroft stated in evidence that of the six million tons of Bessemer ore imported by this country in 1909, nearly five millions came from Spain. With the exception of 62,000 tons from Newfoundland, no ore was imported during that year from the Dominions. Twenty-five years hence the Spanish supplies would probably be exhausted. He suggested that the Dominions might, with advantage, provide more money for the geological survey of the territory under their control, and communicate the results of the surveys as rapidly as possible to the Iron and Steel Associations of this country. The indication of large deposits, especially of Bessemer ore, accessible for shipment anywhere in Eastern Canada or Newfoundland, would promptly be investigated in detail by British makers of iron and steel, and ample capital would soon be found if the deposits warranted development. He said that in 1905 Great Britain imported 31 per cent. of the total ore consumed, Germany 9·3 per cent., and America 4·9 per cent.

Arbitration in the Northern Steel Trade.—At a recent meeting of the Industrial Council evidence was heard as to the procedure in existence in the iron and steel, cement, and other trades, for the settlement of disputes. Among the witnesses examined was Mr. James Cox, Darlington, secretary of the Associated Iron and Steel Workers of Great Britain. He said that there was a sliding scale in the North of England formed by them in connection with their Board in 1888. Similar scales governed the Midland districts, and extended also into Wales. The sliding scale of a district was based upon a percentage of prices. They had hundreds of agreements suited to the requirements of different working mills. During his connection with the Association, which dated from 1891, agreements had been carried out to the letter by employers. There had occasionally been one or two lapses, but these had been infinitesimal. He attributed the success of their agreement to the honourable conduct on both sides, assisted by the strong organisation on both sides. They had Conciliation Boards in the North of England, Midlands, and Wales, and the bulk of the employers and the men were connected with the Boards. There had been no difficulty experienced in non associated employers maintaining agreements. The Association of which he was secretary had 10,000 members, and there were a large number outside. Non-associated employers and men were governed by a general agreement. If an employer did not accept the contract, his ordinary workmen looked elsewhere for employment, and he was left with incompetent workmen. He did not favour legislation, and thought that all that was necessary in relation to agreements could be done without the intervention of the law.

New Works for the Construction of Diesel Engines.—With the object of developing oil engine construction and also coping more successfully with the general expansion of their business, Messrs. Swan, Hunter, & Wigham Richardson, Ltd., have recently embarked upon a complete re-organisation of their engine works. This department is in course of removal to a new site within the Neptune Shipyard, where it is intended to erect entirely new workshops. The existing engine works buildings will be used for the shipyard blacksmiths, plumbers, and angle-smiths. The new buildings will adjoin the existing boiler-shop, and will measure about 300ft. by 200ft., divided into six bays, and comprising a combined machine and erecting shop. For some time past the firm have been actively engaged in studying and developing Diesel oil engine construction. Two years ago they completed the "Toiler," a twin screw cargo ship, which was the first oil-engined vessel to cross the Atlantic. This was at once followed by the "Calgary," a similar twin-screw steamer for the same owner, Mr. James Playfair, of Midland, Ontario, and is now trading on the great lakes of North America. The firm have now in hand for British owners two much larger cargo boats, each of 5,000 tons dead weight. In addition to these two ships, the firm have an order for another interesting vessel, which is being built to the order of the Electric Marine Propulsion Company, Ltd., for the Montreal Transportation Company, and intended for service on the Canadian lakes. This will be the first large vessel designed for propulsion by power transmitted electrically from the engine to the propeller. The designs of the engines have been executed by Mr. Henry A. Mavor, of Messrs. Mavor & Coulson, of Glasgow, who have already tried this system on a small experimental vessel called the "Electric Arc." The deadweight cargo capacity will be about 2,500 tons. The machinery will consist of two 300 h.p. high-speed Diesel engines, each with its own alternating-current generator and exciter. Just ahead of the thrust block, there will be a specially-designed motor, operating a single propeller and reducing the 400 revs. per minute of the Diesel engines to about 80.

Trade Circulars and Catalogues.—We have received from Messrs. Drake & Gorham, Ltd., Victoria Street, Westminster, a copy of their new catalogue and price list relating to their later types of electric lamps and lamp fittings.—Messrs. W. T. Glover & Co., Ltd., Trafford Park, Manchester, send us a neatly bound waistcoat pocket book of electrical mining rules and data which is convenient, and will doubtless be appreciated by mining engineers.—Messrs. Siemens Bros., 39, Upper Thames Street, London, E.C., send us a copy of their price list relating to electrical drilling machines.—Electric and Ordnance Accessories Company, Ltd., Aston, Birmingham, send us a catalogue and price list of their specialities in the way of electric heaters and glow lamp radiators. — Messrs. Galloways, Ltd., Manchester, send us a sheet of illustrations of modern engine and boiler installations which they have either made or are prepared to undertake. These cover nearly every requirement of power practice, and from a circular accompanying it we gather that the firm are preparing a scheme with the object of extending its operations, and we are pleased to learn at the same time that the firm are well booked with orders ahead.—Messrs. Mather & Platt, Ltd., Manchester, send us a descriptive circular of their duplex patent valveless gas engines, the features of which were fully described and illustrated in Mr. A. E. L. Chorlton's paper before the Iron and Steel Institute and reproduced in our columns. The comparatively high costs of gas-power plants have hitherto militated against their extensive adoption, and the Duplex gas engine, it is claimed, goes far to nullify this objection, involving less initial cost and foundations, engine-house, &c., than other designs have up to the present required.—From Messrs. Geipel & Co., St. Thomas Street, London, S.E., we have received a descriptive pamphlet of information respecting aluminium conductors. The pamphlet contains a table of details of aluminium conductors which will be useful to anyone contemplating their use, and the firm state they will be pleased to forward a copy of this to any reader who cares to communicate with them.—The Sun Electrical Company, Charing Cross Road, London, W.C., send us a catalogue of their electrical heating specialities, which illustrates a number of useful little designs for domestic use, and including also some handy soldering and branding irons.

The Latest Submarine.—Messrs. Vickers, Ltd., launched from their yard at Barrow on the 12th inst. Submarine "E 6" for the British Admiralty. The vessel is one of the most advanced type, possessing qualities which enable her to operate far out at sea. She will be propelled, either afloat or submerged, at a much higher speed than submarines previously built.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 58, New Bailey Street, Manchester.

MECHANICAL, 1911.

Removal of moisture from wet carbonised peat. Rigby & Testrup. 16958.
Scavenging and charging arrangements for internal-combustion engines. Kylliainen. 16965.
Flying machines and airships. Mills. 17130.
Carburetters for internal-combustion engines. Gottmann. 19356.
Furnaces for steam boilers. Ramsbottom. 21195.
Flying machine. Braun. 21417.
Valve for blowing engines. Iversen. 23354.
Internal-combustion engines. Twombly. 23445.
Clutches for power presses. Rhodes. 23583.
Method of extracting carbonic acid from the exhaust gases of a gas engine. Maschinenfabrik Surth Ges. & Volland. 23592.
Devices for electrically driving planing machines. Wiesengrund. 23639.
Apparatus for measuring and recording the quantity of liquids passing through orifices or over weirs. Woodroffe & Boultbee. 23679.
Processes and apparatus for the direct production of iron and steel. Herrmann & Otto. 23861.
Airships. Janin. 24033.
Nozzles or nozzle branches for turbines. Churchill-Shann. 24041.
Apparatus for consuming smoke in steam boiler furnaces. Wilde and Hargreaves. 24064.
Carburetters for paraffin and other heavy oils. Davis. 24106.
Pipe joints. Schomburg. 24117.
Burners for gaseous liquid and solid combustibles. Gautreau. 24127.
Compressed-air brakes for railway vehicles. Preston. 24152.
Automatic couplings for railway vehicles. Allison. 24167.
Steam superheaters for locomotive boilers. Robinson. 24174.
Manufacture of forged car wheels. Hansen. 24246, 24248, and 24249.
Hoisting and transport apparatus. Essberger. 24285.
Fluid-pressure braking apparatus. Cloud. 24387.
Method for cleaning the tubes of boilers. Roots, and Internal-Combustion Engine Cleaning Company. 24485.
Tube-cleaning apparatus. Brindley, and Boiler Scalers, Ltd. 25703.
Suction and pressure dredgers. Van Wienen. 25958.
Vaporisers for internal-combustion engines. Crosbie. 26337.
Pile-drivers. Leighton. 26375.
Trip gears primarily applicable to testing machines. John Barham Carslake and Arthur Henry Gibson, and Goulding. 26480.
Rotary valves for internal-combustion engines. Ritchie. 27228.
Means for burning liquid fuels in furnaces. Gordin. 27338.
Manufacture of lubricative engine packing. Oddie. 27350.
Change-speed gearing. Jones & Jones. 27459.
Foundry moulding machines. Smith. 27725.
Friction clutches. Marks. 28275.
Two-stroke internal-combustion engines. Silvestri. 28364.
Coal-washing plant. Thomson. 28548.
Pumps for elastic fluids. Cash. 28981.

1912.

Furnaces of steam generators. Whitehead. 934.
Lathe for turning cranks. Witteman. 1216.
Gravity conveyers. British Mathews, Ltd., and Pirrie. 1279.
Uniflow or automatic exhaust engines. Sisson. 1605.
Multiple-expansion multiple-crank engines controlled by automatic expansion shaft governors. Sisson. 1606.
Apparatus for heating and purifying feed-water. Muchka. 1959.
Driving gear for motor vehicles. Clark. 3789.
Nut locks. Barclay. 4184.
Centrifugal pumps. Moller. 4304.
Apparatus for making petrolised or air gas. Dick. 4418.
Gear-cutting machines. Fawcus. 4693.
Tube rolling apparatus. Pittsburgh Steel Products Company, Brock, and Selkirk. 4794.
Draining water from steam cylinders, valve chests, &c. Yates. 4812.
Compressed-air turbines. Fletcher. 5285.
Air tight device for use in connection with the sliding dampers of steam boiler flues. Smalley. 6124.
Dredgers. Watkins. 6264.
Cutters for coal-cutting machines. Mavor & Coulson, Ltd., and Davies. 6356.
Mine carriage and elevator automatic safety brakes. Von Daam. 6700.
Water gauges. Mauger. 6985.
Turbines. Upson. 8351.
Two-stroke explosion engine. Tessé. 9061.
Throttling device for pipes or tubes or pumps. Adams. 9171.
Propellers. De Vallat. 9330.
Pistons for internal-combustion engines. Knowles. 11077.
Rotary engines and pumps. Parsons & Myers. 11446.
Method of washing gases or vapours and apparatus therefor. Lymn. 11452.
Clutches. Guttner. 11933.
Flying machines. Stodder. 13104.
Water-heating apparatus. Brierley. 14800.
Means for preventing creeping of railway rails. Dinklage. 16521.
Steam superheaters. Sugden. 17478.
Automatic lubricating apparatus for elevators and conveyers. Wetzel & Kuntz. 17782.
Spring journal bearings. Held. 19412.
Helical propellers. Magnenat & Grobety-Matthey. 19698.
Centring tools for use on lathes. Moffat. 19784.
Coal conveyers. Seppel & Dracke. 20385.
Pump for forced lubrication. Daimler-Motoren Ges. 20428.
Airships. Janin. 22627.

ELECTRICAL, 1911.

Electric battery lamps. Eley. 8446.
Application of radio active phenomena to telephony. Vojen. 17028.
Electric railway systems. Stuart. 18998.
Switching apparatus for interconnecting the lines of an automatic telephone system. Western Electric Company. 21259 and 21260.
Dynamos. Parsons & Law. 21489.
Protection of feeders of electrical distribution systems. Merz and Hunter. 24030.
Battery switches. Marks. 24460.
Electric light fittings. Hollick. 24584.
Water cooled resistances. Emmet. 24679.
Apparatus for photometrically testing burners for gas or electricity. Gordon. 27978.
Fusible cut outs for electric circuits. British Thomson-Houston Company. 28199.
Production of electrical oscillations adapted for wireless transmission. Heinicke & Jasper. 28351.
Electric automatic switch gear. Crompton & Co., and Murray. 28520.

1912.

Electric couplings. Appenzeller. 4303.
Page-printing telegraph receivers. Etinne. 4584.
Dynamos. Fouque & Ruelle. 6099.
Electro-magnets. Dowdell. 9804.
Telephone indicating and metering apparatus. Von. Laskowski. 12929.
Apparatus for selective electric signalling. Nicholson. 13,430.
Means for telephonic communication with mine cages. Reineke. 19102 and 19103.
Electric furnaces. Massip. 19172.
Switching apparatus for interconnecting the lines of an automatic telephone system. Western Electric Company. 20943, 20944, and 20945.
Telephone systems. Western Electric Company. 20946.

METAL QUOTATIONS.

TUESDAY, NOVEMBER 19TH.

Aluminium ingot	85/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	120/- ,,
Antimony ......£39/-/- to	£40/-/- per ton.
Brass, rolled	$9\frac{1}{8}$d. per lb.
,, tubes (brazed)	$11\frac{1}{2}$d.
,, ,, (solid drawn)	$9\frac{3}{4}$d.
,, ,, wire	$9\frac{1}{8}$d.
Copper, Standard	£78/2/6 per ton.
Iron, Cleveland	68/3 ,,
,, Scotch	74/3 ,,
Lead, English	£18/15/- ,,
,, Foreign (soft)	£18/5/- ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/12/6 per bottle
Silver	$28\frac{15}{16}$d. per oz.
Spelter	£26/10/- per ton.
Tin, block	£227/15/- ,,
Tin plates	15/6 ,,
Zinc sheets (Silesian)	£31/5/- ,,
,, (Stettin; Vieille Montagne)	£31/10/- ,,



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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Engineering Research Laboratories.

In a long letter to the "Manchester Guardian" last week, Dr. Nicolson, of the Manchester School of Technology, contrasts the up-to-date equipment of continental laboratories with the backwardness of British ones, and the generous support accorded to such institutions by foreign firms with the laissez faire attitude of employers here. The comparison leads him to rather pessimistic conclusions and raises a few points which we think call for reply. At the outset he raises the question as to what is the proper function of a technical laboratory. Should it be confined to the training of its pupils to fit them for entry into engineering establishments or should it be extended to research work that affects particular industries, and which some argue should be carried out by the firms immediately concerned? It is in protesting against this latter view that he draws a doleful contrast between the equipment of the Manchester Technical School and that of a number of continental ones he has recently inspected. His statement that when the former was equipped under his direction 12 years ago it "would bear comparison with anything of the kind either in Europe or America," whereas it is now so "completely left behind" that in his opinion it is not "possible for us by the most strenuous exertions ever to make up to the German laboratories again," certainly does give food for reflection, and possibly suggests conclusions different to those drawn by Dr. Nicolson. But putting this aside for the moment, some of his statements as to what is being done abroad are worth noting. All the high school laboratories "either have had or are having their heat engine laboratories completely rebuilt and re-equipped on a scale which can only be described as colossal." The new Dresden Laboratory, he informs us, has a floor area for heat engines alone equal to the whole ground floor of the Manchester School, and the equipment alone will cost over £20,000. The Berlin heat engine laboratory now consists of a huge machinery hall 250ft. in length by 50ft. in breadth, in addition to an annexe,

not to mention another large building for motor-car testing, besides others round the High School at Charlottenburg. In Zurich a large plant is being installed and equipped at great expense under Prof. Stodola's direction. At Munich about £25,000 is being spent on buildings and equipment of a heat engine department under Prof. Schröter. Dr. Nicolson is not clear as to how the expense of all these big extensions and equipments is apportioned, but we gather substantial support is being accorded by engineering firms and societies. However, that is a detail. It is well to have the facts and look them squarely in the face. But when we do this and admit to the full the defects in technical training of British engineers, we fail to arrive at his despondent view of their shortcomings. If called upon to express their attitude towards continental methods of technical training and research he thinks they would probably reply as follows: "We are here to do business and not to support research in technical schools. So long as we can make and sell all the machines we want and make all the profit we require, we do not need to go in for all this minute German theoretical examination of parts and unnecessary elaboration in form and finish. Our customers are quite satisfied with our products, and that is really all we need care about. We are quite willing to give our support to the technical schools as the means of training our young engineers, but to endow them as large experimental stations forming adjuncts to the workshops, which is what you say the Germans are doing, is a thing beyond our experience and appears to us to be foolishly putting a large premium on unnecessary pedantry."

Let us take it that this fairly represents the views of the majority of engineers. Dr. Nicolson demurs to it on the ground that the "satisfaction of the purchaser" is a defective standard of excellence, since he seldom knows what he ought to get, and consequently the manufacturer is not constrained to rise to the best he can give, whereas his continental rival is. But is this correct? "The satisfaction of the purchaser" implies a great deal more as a rule than is suggested by Dr. Nicolson. It is seldom secured until the British manufacturer has run the gauntlet of comparison with every rival, whether home or foreign, and in respect not only to quality but also in price and efficiency, for, be it remembered, he has no tariffs to defend him. If there has been one complaint more loudly trumpeted than another by uninformed critics respecting British traders' attitude to customers, it has been that "he will insist on supplying a first-class article and will not, like his continental competitor, supply just what the customer wants, although it may be cheap and nasty." We have every sympathy with Dr. Nicolson's plea for the more frequent employment of the staffs and equipment of British engineering colleges by the heads of engineering firms. The closer the intimacy, the better for both. By all means let the resources in trained men, instruments of precision, and other appliances of such institutions be availed of as much as possible. But when all is said and done, we do not expect, nor do we think, as Dr. Nicolson appears to do, that such a relationship as exists in Germany between engineering firms and technical schools is the best for this country. His dictum that "either the British or the German method is the right one" reveals a looseness of reasoning we hardly expect from him. The methods may be different and yet both right for their respective conditions, and college professors seem to forget it when comparing the lavish expenditure of other countries on technical institutions with our own. German polytechnics have evolved naturally from that country's admirably co-ordinated system of education from the elementary school upwards, and compared with which we are in some respects sadly behind. Their technical and commercial development has, so to speak, been grafted on an educational stem, whereas with us the reverse has been the case. It may or may not be the best way, that is a matter of opinion, but we have to take fact as it is, and Germans are by no means unanimous in the belief that their methods of technical training is the best; more than one educationist has deprecated their methods by comparison with our own.

It does not follow that because money is not lavishly spent on British technical schools that British engineers are insensible to the value of research work. Investigations, often involving great expense, are being made continuously in works all over the country. No progressive firm can get along without, but those who make them have as a rule little time or inclination to publish their results, and this fact should not be overlooked when comparisons are made. Evidence of the sort of thing that is taking place is occasionally afforded, as it was on Saturday last at the Manchester Association of Engineers, when Mr. Vernon outlined the scientific methods that are being pursued at Coventry to improve the efficiency of milling machines, and quite recently, before the same society, Mr. A. E. L. Chorlton described the marked advances made by a Manchester firm in big gas engine designs. We need not labour these illustrations. A glance at the proceedings of our engineering societies will supply any number of them, and where, we would ask, are engineering societies more numerous, more specialised, or more virile than in this country? British engineers have for generations been taught to rely upon themselves and the habit has become ingrained. It may be that this tends to make them in some ways rather conservative, but we must not forget that commercial vigour is maintained by the fact that they have to stand four square to all the winds that competition can blow, unsheltered by tariff or privilege. That they have stood it well a review of our trade clearly shows. If it does not spell as much profit to them as does sometimes to continental rivals, it is their misfortune rather than their fault, and we would not have it otherwise, for their success stands on an unshakable basis. If in certain directions continental engineers beat us we need feel neither surprise nor regret. We cannot have a monopoly of every industry or be more than fully occupied, and what country can show on the whole a lower rate of unemployment in engineering generally, or a higher rate of remuneration to its workers? The doctrine of British decadence, which appears to have affected Dr. Nicolson, has been preached too much, and on behalf of engineers generally we strongly protest against it. They may perhaps in the past have been too prone to rely on rule of thumb and under-estimate the value of science, but that complaint has very limited justification to-day. Unfettered competition is ever spurring them on, and if they do not follow German methods in looking to technical research laboratories and college professors for salvation in their daily difficulties they are not less alive to the value of scientific investigation. Manufacturers may certainly be excused if they view with doubt the wisdom of renewing expensive college equipments that become obsolete and hopelessly behind in a few years. Better, they may argue, conduct our own research work as we do now and limit the function of technical schools to the training of young engineers. This may appear a cramped interpretation of a professor's duties, but after all it is a very essential part of them, and we fear sometimes it is overlooked. The more intimate the connection of a teacher with current engineering problems and difficulties, and the more efficient we readily admit he is likely to be, but the proper apportionment of his time and energies to such work requires dis-

crimination, unless he is solely devoted to research work, and perhaps it might be desirous for engineers sometimes to take a broader view of the help that may be derived from college professors and technical laboratories. At the same time, it should be recognised that many questions can be better investigated in the workshop than in the college, owing to commercial and other considerations only known to those immediately concerned. Besides, college research work must of necessity be public, and the extent to which it can be undertaken by institutions run with public funds raises other questions which may not permit of being answered the same way in this country as they are on the Continent. No harm, of course, can come, as Dr. Nicolson observes, from a discussion of every aspect of engineering research, and for this reason we shall be pleased to open our columns for the expressions of opinion from all who are interested.

MECHANICAL ANALYSIS OF IRON AND STEEL.

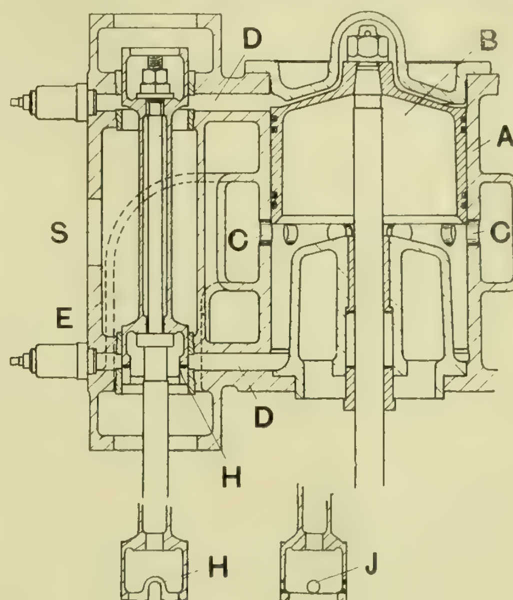
A lecture on the "mechanicalising" of methods of chemical analysis as applied to iron and steel manufacture was delivered by Messrs. C. H. and N. D. Ridsdale, of Middlesbrough, at a recent meeting of the Sheffield Society of Engineers and Metallurgists. The lecturers explained that the object in adopting this new method was to reduce the personal factor. This was where the errors of analysis were most likely to arise. For a basis, the best proved methods were taken, and so arranged that, although the preliminary and finishing operations were still unavoidable, the main portion, which hitherto had depended largely on the judgment of the analyst, was cut right out, and with it a corresponding risk of the estimation being wrong. The same essential chemical reactions were brought about, but from eight to 20 operations were replaced by one or two. It was pointed out that the principle was widely recognised that where the personal element was minimised greater accuracy was obtained. Various ways of analysis by ordinary methods were compared in detail with corresponding "mechanicalised" types, and the saving in time, number of operations, labour, &c., illustrated by lantern slides and tables. Although so far methods had only been devised for phosphorus and manganese, these covered a wide field of application, and matters were by no means at a standstill. Progress had been made in many details in the last few months. The latest, a method for determining pure phosphorus with the separation of arsenic—a method vital to all steel analysis, which had hitherto taken practically a day—could now be done in an hour with accuracy. The advantages of enabling the laboratory to deal with much larger quantities of work were pointed out. An example was quoted where 240,000 analyses per year were now done easily, though formerly 83,000 had severely taxed a slightly larger staff. This permitted better organised chemical control of the works, and proved of considerable commercial and practical value. Although the first publication of these modes of procedure was only some 18 months ago, already over 20 firms had adopted the method. It appeared as if that "mechanicalised" analysis had come to stay.

Fatal Boiler Explosion at Cambuslang.—A boiler exploded early on Friday morning last in the works of the Steel Company of Scotland, Ltd., at Hallside, Cambuslang. As a result two workmen were so badly scalded that they subsequently died.

The Water-cooled Blast Furnace.—Thin-lined furnaces, cooled by a film of water, in place of the ordinary solid brick lining, were tried some years ago at the Gelsenkerchen works in Germany. Since then, they have been adopted in several places in the United States, notably by the Carnegie Steel Company and the Illinois Steel Company, and more recently in the works of the Tennessee Coal, Iron, and Steel Rail Company, and of the Detroit Iron and Steel Company. They are claimed to show a distinct superiority over the thick-lined furnace in operation.

SISSON'S UNIFLOW STEAM ENGINE.

As is well known in uniflow engines, the steam is admitted by any suitable form of valve, which usually only deals with the admission and cut-off, and does not afford any exhaust passage, and the exhaust of the steam is provided for by an annular port, or a ring of ports which are exposed by the travel of the piston near and at the end of its stroke, and closed again by its return, thus dispensing with any ordinary exhaust valve arrangement, and securing higher compression as well as much diminished condensation losses. In vertical uniflow engines of the double-acting type actuated by steam which may contain water, the exhaust from the upper end of the cylinder permits free exit for both the water and the steam, but water lying in the lower part of the cylinder would not be freely exhausted, and would be liable to accumulate,



Sisson's Uniflow Steam Engine.

involving considerable increase in the terminal pressure, frequent blowing of the escape valves, if such be fitted, and risk of damage to the cylinder.

To obviate these defects, while at the same time retaining the advantages of the uniflow engine, the arrangement illustrated herewith has been patented by Mr. William Sisson, of Hucclecote, Gloucester. In this design the steam admission valve or valves act also as automatic drain valves, the ports being suitably arranged for drainage so that water lying at the bottom of the cylinder has afforded to it a small drainage passage independent of the annular automatic exhaust passage, while the timing of this drainage opening and closing is such as not seriously to interfere with or affect the uniflow system of working, but it is arranged to close a little later than the automatic exhaust, so that the rise of pressure which results from the closing of the latter shall assist in expelling the water through the supplementary drain valve.

Referring to the illustration, A is the cylinder of the engine, provided with a ring of ports C through which the steam is exhausted near and at the end of the stroke of the piston B at either end of its travel. D are the steam admission ports, E a piston valve provided with the small drainage passages H or holes J. It will be seen that as the piston valve E continues to move upwards, supplying steam to the upper side of the cylinder A while the piston B travels downwards and in this movement closes in the ordinary way the automatic exhaust port C, the small auxiliary drainage passages H will remain open for a considerable period and will allow passage to condensation or priming water which may be in the lower part of the cylinder, and will do this without interfering seriously with the compression and thermal advantages attained on the uniflow system of working. The upper end of the piston valve E is of ordinary form without auxiliary drainage openings, as these are not required there, because the water which may find its entrance to the upper part of the cylinder will lie chiefly on the upper side of the piston, and will naturally be swept out by the exhaust steam as soon as the upper edge of the piston B begins to expose the automatic exhaust openings C.

SOME MILLING EXPERIMENTS.*

BY P. V. VERNON, M.I.MECH.E.

ALTHOUGH the primary object of the experiments recorded in this paper was the improvement of the machine, it was realised that they would also provide much valuable data from which the output of the machines on general work could be estimated, and that a good deal of indefinite knowledge of milling generally would be rendered exact. Apart from the machine itself, it was expected that something fresh would be learned as to what a modern milling cutter could be made to do. Now that the experiments have been completed, it is satisfactory to know that these anticipations were not without justification.

Returning to the direct object of the experiments, viz., the improvement of the machine, it was felt that knowledge was required of the necessary strength, proportions, and wearing resistance of the driving mechanism, feed mechanism, and other parts of the machine, and as to the proper materials from which the members carrying the heavy stresses should be made. This view was supported by the fact that earlier experiments made with other machines had proved of great value and had led to many improvements both in design and in material.

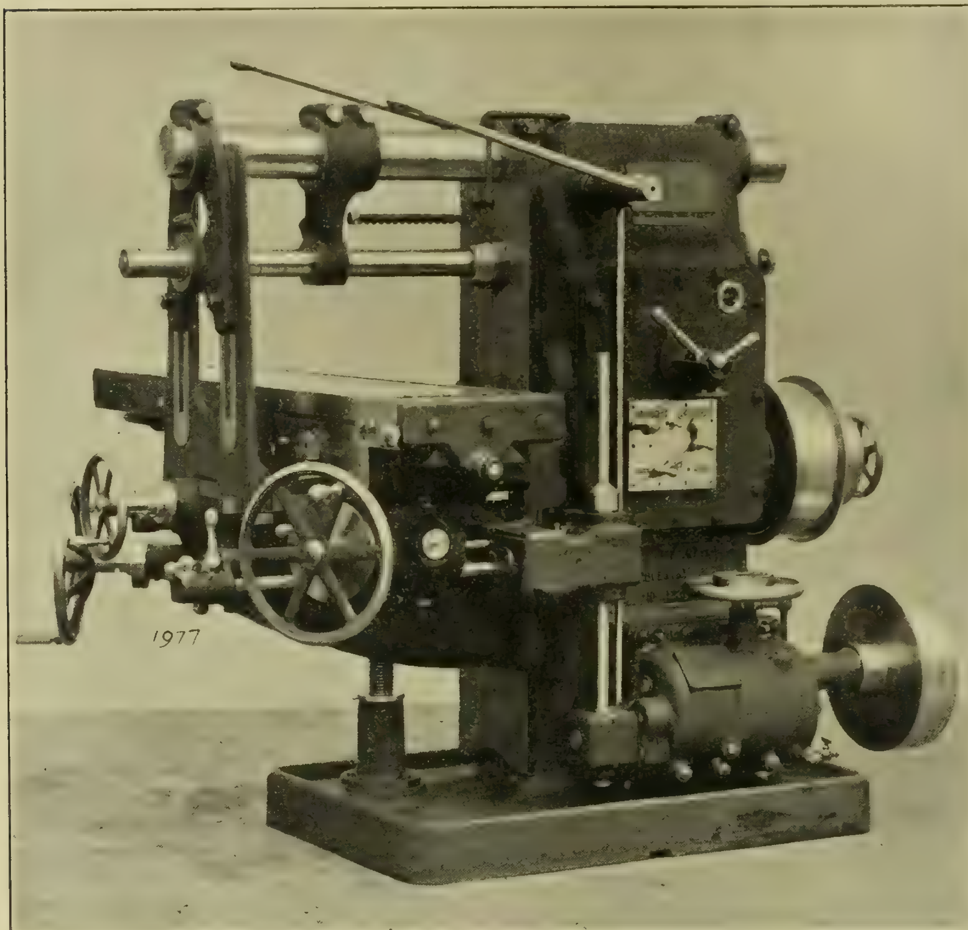


FIG. 1.—No. 22 SINGLE PULLEY HORIZONTAL MILLING MACHINE. MESSRS. ALFRED HERBERT, LTD., COVENTRY.

The experiments selected for description were applied to a horizontal milling machine of heavy type (see Fig. 1). The machine was built solely for experimental purposes, so that considerations of time and cost of production were only of secondary importance, the paramount idea being to produce the best possible machine, to test it thoroughly, and then to modify or re-design any parts that might not work satisfactorily or that might be found to be otherwise capable of improvement. It was also considered necessary to make careful tests of the physical properties of the material operated upon and to observe and record all the material conditions of the experiments. The facilities offered by the experimental workshop and by the testing laboratories of the makers were invaluable in this direction. The final results of the tests showed that some real progress in metal removing by milling cutters, with a machine of the size tested, had been achieved.

The machine was a heavy "single pulley" horizontal machine of knee type and embodying the following leading particulars: Longitudinal feed 42in., transverse feed 13½in., vertical feed 21in., working surface of table 68in. by 17in., number of tee slots in table three, width of tee slots in table ¾in., diameter of "single pulley" 16in., width of belt 5in., speed of "single pulley" 400, belt speed in feet per minute 1,675, maximum gear ratio 24·4 to 1, taper hole in spindle No. 12, number of speeds 16, range of speeds 16·4 to 427, number of feeds 18, range of feeds in inches per minute ⅝in. to 22½in., weight 8,652lbs.

Fig. 2 is a diagram of the driving gears, and the particulars below the figure indicate the various combinations of gearing which give the 16 spindle speeds. All the gears were of eight diametral pitch, except N and Q, which were six pitch 1⅞in. wide, and the narrowest gear in the train was 1⅜in. wide. The main driving pulley was mounted on large annular ball bearings running on a fixed sleeve, to reduce friction and to prevent wear or transverse stress on the shaft from the pull of the belt. The gears throughout were all of steel, and all the driving gears, except the pinion N, were hardened on the teeth. The maximum gear tooth velocity was 628·3ft. per minute on the pitch line, and the gearing worked without vibration or undue noise. The driving gear, feed gear, and, in fact, all the internal mechanism was lubricated by a submerged force pump which continually poured a large excess of oil over all the gears and through all the bearings. After leaving the pump the oil passed through a wire gauze filter to arrest any solid matter that might have been carried along with it.

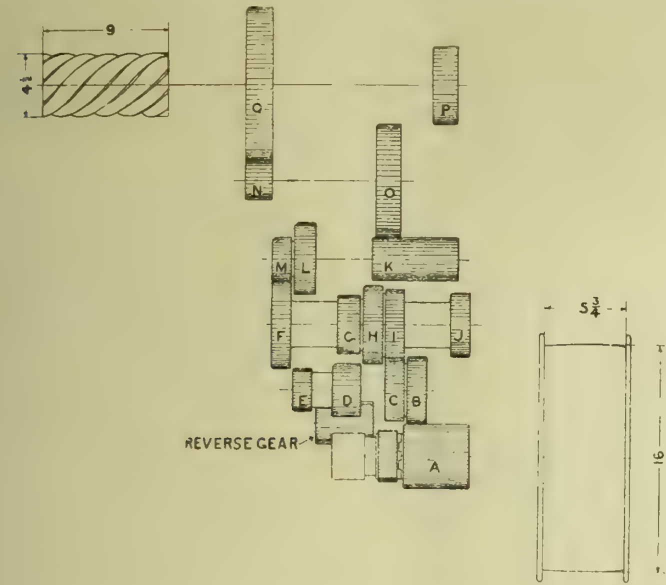
The machine could be started and stopped by a friction clutch on the first driving shaft. The feed motion was driven from this shaft and naturally started and stopped in harmony with the spindle of the machine, but was independent of the spindle speeds in rate, so that the feed in inches per minute could be read directly from the feed-control dial, no matter what spindle speed was in use. The whole feed mechanism was designed on liberal lines, and proved to be well up to its work, no organic failures being recorded in any of the tests. Several modifications of details were, however, made at the conclusion of the preliminary tests.

The machine was driven from a motor fixed to the floor. The motor, which was specially installed for experimental work, was of 220 volts, direct current, compound wound, interpole type with 3 to 1 speed variation, giving 30 b.h.p. at all speeds on normal full load, with a guaranteed and tested overload capacity of 75 per cent. for one minute, 33⅓ per cent. for 15 minutes, and 20 per cent. for two hours. The speeds of the motor ranged from 320 to 960 turns per minute in 30 steps and the motor could be reversed when required.

The motor had been carefully calibrated by the makers and was provided with tested efficiency and power charts by which the actual brake horse-power at the pulley could be read off from the ammeter readings. The shunt current was not included in the charts, as the horse-power could be obtained from the armature current input. The ammeter from which the power readings were taken was really a millivoltmeter furnished with shunts by which three different scales of read-

* Abstract of paper read before the Manchester Association of Engineers, November 23rd, 1912.

ings could be used, in the ratio of one, 10, and 100. The use of the shunts enabled large divisions to be used for light loads so as to provide a degree of accuracy of reading that would have been impossible with a single scale covering the whole range, on account of the fineness of the graduations for the small loads. The switches by which the shunts were put into operation were provided with mercury-cup contacts for the purpose of avoiding errors that might otherwise have been



SPINDLE SPEEDS.

SPEEDS	16·5	20	25·5	31·5	39	48	60	75	93	115	144	179	222	275	343	427
GEAR COMBINATIONS.	AB EF GL KO NQ	AB DH GL KO NQ	AB CI GL KO NQ	AB BJ GL KQ NQ	AB EF FM KO NQ	AB DH FM KO NQ	AB CI FM KO NQ	AB BJ FM KO NQ	AB EF GL KO OP	AB DH GL KO OP	AB CI GL KO OP	AB BJ GL KO OP	AB EF FM KO OP	AB DH FM KO OP	AB CI FM KO OP	AB BJ FM KO OP

FIG. 2.—GEAR DIAGRAM OF NO. 22 HORIZONTAL MILLING MACHINE.

caused by bad electrical connections and which would have been greatly magnified by the millivoltmeter. The connection between the motor and the machine was by a double leather belt 5in. wide with a scarfed and cemented joint. The motor pulley was 16in. diam., the same as the pulley on the machine.

The machine being of new design throughout and very much more powerful than any previously constructed, it was expected that certain defects would manifest themselves when taking heavy cuts; so that before making systematic power tests it was decided to take some preliminary cuts of a more or less destructive nature with the object of taking the measure of the machine and of discovering and removing any weaknesses at the earliest possible stage so as to ensure continuous running during the power tests. The first cuts were, therefore, taken on a cast-iron test block 5in. wide using a 3in. coarse pitch spiral cutter made of high-speed steel mounted on a 1¼in. arbor and running at various speeds. The greatest output was attained running at 93 turns per minute (= 73ft. per minute) with a depth of cut of ·625in. and a feed of 11 $\frac{3}{16}$in. per minute. This gave a maximum production of 34·96 cub. in. of metal removed per minute, but the arbor was eventually twisted and, of course, put out of action. The next cuts were taken with a 3½in. cutter 9in. long on a 1½in. arbor with a test block 8in. wide. In this case the maximum output was reached at 75 turns per minute (=70ft. per minute) with a depth of cut of ·4in. and a feed of 13⅞in. per minute. For these cuts the arbor stood very well and the output reached 44·4 cub. in. per minute. The results of these preliminary tests with the 3½in. cutter, which were made on cast iron only, are shown by Table I.

TABLE I.—*3½in. High-speed Cutter, 8 Teeth, 1½in. Hole. Milling Cast-iron Block 8in. wide at 75 turns = 70ft. per minute.*

(Power required to run motor and machine light ·7 net H.P. has been deducted from the recorded H.P.'s to give the figures in the Table.)

Depth of Cut.	Feed Measured.	Net H.P.	Metal Removed. Cubic Ins. per min.	Metal Removed. Cubic Ins. per H.P. min.
·24	21	27·3	40·32	1·47
·25	21 $\frac{3}{16}$	23·7	42·40	1·78
·26	17	24·9	35·84	1·44
·28	17 $\frac{1}{16}$	30·8	38·21	1·24
·30	16 $\frac{11}{16}$	30·8	40·04	1·31
·32	13 $\frac{11}{16}$	27·3	35·04	1·28
·34	13⅞	26·1	37·73	1·44
·36	13⅞	30·8	39·96	1·29
·375	13 $\frac{11}{16}$	29·6	41·06	1·38
·40	13⅞	33·3	44·40	1·33
·42	11⅝	30·8	39·06	1·26
·44	10 $\frac{15}{16}$	23·7	38·50	1·62
·46	9 $\frac{3}{16}$	28·6	33·81	1·18
·48	9¼	27·3	35·52	1·30
·50	9⅛	24·9	36·50	1·46
·55	9⅛	29·6	40·15	1·35
·60	7 $\frac{5}{16}$	30·8	35·04	1·14
·625	7 $\frac{7}{16}$	27·3	37·18	1·36
·70	7 $\frac{3}{16}$	29·6	39·75	1·32
·75	5 $\frac{15}{16}$	28·6	35·62	1·25
·80	5 $\frac{15}{16}$	30·8	38·00	1·23
·85	4 $\frac{9}{16}$	29·6	31·02	1·04
·90	4 $\frac{13}{16}$	28·6	34·56	1.20
·95	3 $\frac{15}{16}$	26·1	29·92	1·14
1	3 $\frac{15}{16}$	29·6	31·50	1·06
1·05	3¼	24·9	27·30	1.09
1·1	3¼	26·1	28·60	1·09

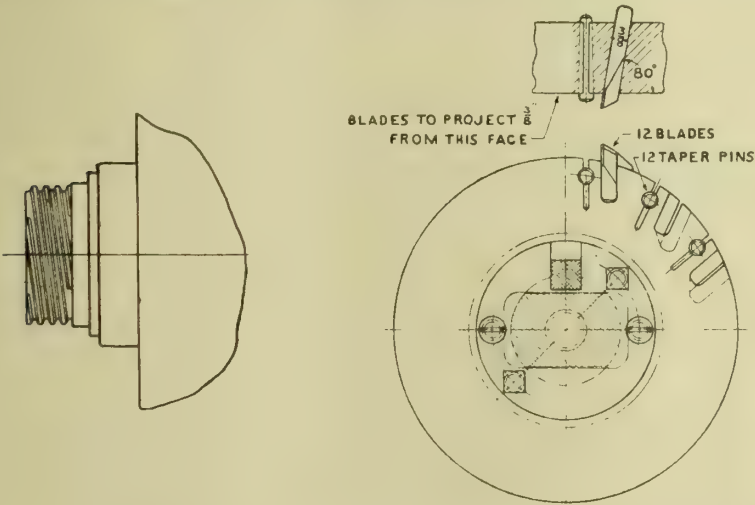


FIG. 3.

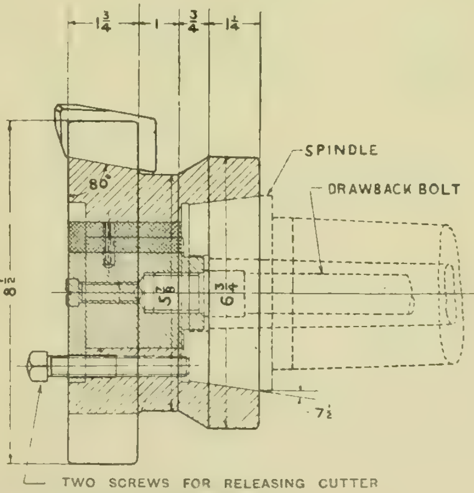


FIG. 4.—9IN. DIAMETER INSERTED TOOTH-FACE CUTTER.

It was not certain that this cutter had exhausted the power of the machine, so it was decided to make further tests with a 4½in. cutter 9in. long of coarse pitch, mounted on a 2in. arbor which gave ample strength and stiffness. A few preliminary tests were made with this cutter and arbor running at various speeds, with the result that the next thing to fail was the main spindle of the machine, the rectangular box-clutch nose by

which the arbor was driven being badly distorted. The spindle was of heat-treated Siemens-Martin steel of 48 tons maximum stress and 32 tons yield point, but was not hardened, as, up to the time of the failure of the nose, it had been considered that the greater strength of this material rendered it more suitable than the weaker variety of steel that would

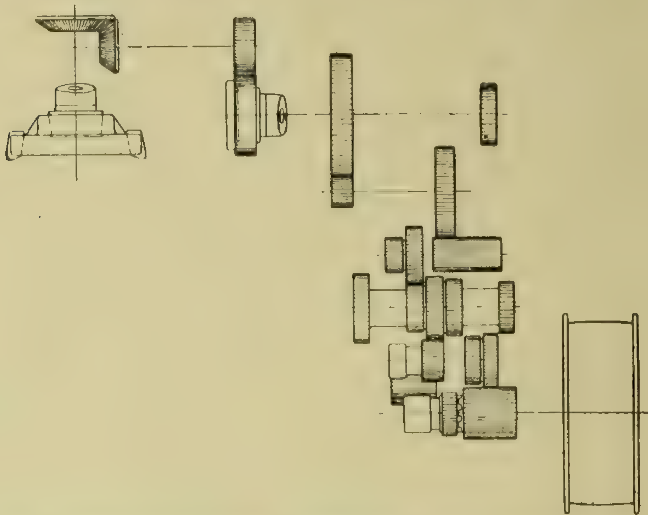


FIG. 5.—GEAR DIAGRAM OF NO. 22 HORIZONTAL DRILLING MACHINE WITH VERTICAL ATTACHMENT.

have had to be used if case-hardened. This was found to be incorrect. After the failure of the box clutch it was decided to try a hardened spindle, but before doing so to use the existing spindle to test the vertical milling attachment which was next put in position. A number of cuts were taken with the vertical milling attachment over the same test block, using a high-speed steel inserted tooth face cutter 9in. diam., screwed upon the nose of the vertical spindle, which was identical with that of the main spindle of the machine. The spindle noses, as first made, are shown by Fig. 3, the diameter being $4\frac{3}{16}$in., and the thread quintuple, the pitch being $1\frac{2}{3}$in.

The face cutter was of the design shown by Fig. 4, except that it was threaded for attachment to the spindle nose. The vertical spindle was driven by spur and bevel gears made of heat-treated 48-ton steel, the first gear being screwed upon the main spindle nose in the same way as the face cutter. Fig. 5 is a diagram of the gear train for driving the vertical spindle.

The result of these tests was that all the gears of the vertical attachment were ruined, the teeth being bent badly out of shape, although none were actually broken. It was also found to be impossible to remove either the face cutter or the gear from their respective spindles in spite of the quick pitch thread. Evidently either both spindles or one spindle and the cutter had to be sacrificed, and as the cutter could be used on a less powerful machine, whereas both spindles were already proved to be wrong in design for heavy work, it was decided to save the cutter and to make two new spindles. Up to this point the experiments had shown that unhardened gears and that the unhardened box clutch were unsuccessful, and that the screwed spindle nose was also a failure. The new gears and spindles were made of a good quality of case-hardening steel, which was carefully heat-treated and hardened. The rectangular box clutch was retained, but was of course hardened. The screwed nose was abolished and a plain taper nose adopted, the design of which is shown by Fig. 6. The new design of spindle nose had a further important advantage over the screwed nose in that it could be used equally well with the spindle running in either direction.

The diameter of the spindle itself was $3\frac{3}{4}$in. at the large end of the front conical bearing, and $3\frac{3}{8}$in. at the seat (just behind the bearing) on which the large driving gear was keyed, and it is interesting to note that there was no trouble whatever caused by chatter or torsional vibration even on the heaviest cuts.

The new face cutter was made to fit the taper nose, and was provided with a driving portion shaped to fit into the

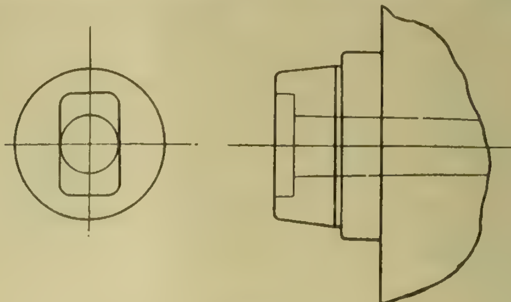
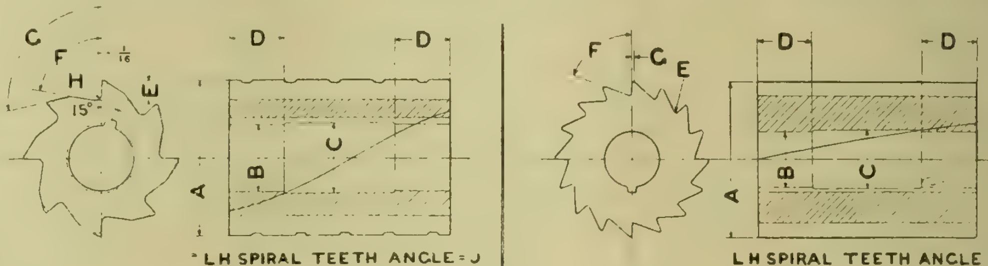


FIG. 6.

box clutch, the cutter being held on the spindle by a draw bolt passing through it from end to end. Fig. 4 shows the face cutter as finally employed. This design proved to be perfectly satisfactory under the heaviest cuts that could be taken, absorbing as much as 42 h.p. The vertical milling cuts were not recorded in detail, as they did not form a complete series, and were only taken to test the spindle noses and the strength of the gearing and shafts.

While the new gears and spindles were being made the machine was dismantled for examination, and it was found that the pinion N, Fig. 2, had failed, the teeth being badly distorted. This pinion, which was in one piece with its shaft, was made of 48 ton steel, and was the only unhardened gear in the whole train. A case-hardened pinion was substituted for it and all trouble ceased, apparently for ever, for at the end of the whole series of tests, the hardened gears showed no signs of wear or of distress, and were in as good condition as when first put into the machine.

Although no failure of the feed motion had occurred during these rather severe tests, yet the speed of the feed box had appeared to be excessive, causing considerable shocks when the feed was changed, and it was therefore decided to reduce the speed by one-third, by enlarging the driven feed pulley before beginning the final tests. The ratio of the gears by which the motion was transmitted from the feed box to the knee was altered at the same time, so as to preserve the original range of feeds. The operating hand wheel for changing the feeds was also arranged to be interlocked with the



COARSE PITCH

DIAM OF CUTTER A	B	C	D	E	F	G	H	J	KEY-WAY	Nº OF TEETH
$2\frac{1}{2}$	1	$1\frac{1}{16}$	$1\frac{1}{4}$	$\frac{3}{8}$	80°	103°	$\frac{1}{8}$ R	$26\frac{1}{2}$°	$\frac{5}{32}\times\frac{3}{32}$	8
3	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{1}{4}$	$\frac{3}{8}$	80°	103°	$\frac{1}{8}$ R	$26\frac{3}{4}$	$\frac{3}{16}\times\frac{1}{8}$	8
$3\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{9}{16}$	$1\frac{1}{4}$	$\frac{7}{16}$	80°	103°	$\frac{1}{8}$ R	26	$\frac{1}{4}\times\frac{5}{32}$	8
4	$1\frac{3}{4}$	$1\frac{13}{16}$	$1\frac{1}{4}$	$\frac{7}{16}$	71°	94°	$\frac{3}{16}$ R	$25\frac{1}{2}$	$\frac{1}{4}\times\frac{5}{32}$	10
$4\frac{1}{2}$	2	$2\frac{1}{16}$	$1\frac{1}{4}$	$\frac{1}{2}$	71°	94°	$\frac{3}{16}$ R	$26\frac{3}{4}$	$\frac{5}{16}\times\frac{3}{16}$	10

FINE PITCH

DIAM OF CUTTER A	B	C	D	E	F	G	KEY-WAY	Nº OF TEETH
$2\frac{1}{2}$	1	$1\frac{1}{16}$	$1\frac{1}{4}$	$\frac{3}{64}$ R	70	$\frac{3}{64}$	$\frac{5}{32}\times\frac{3}{32}$	14
3	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{1}{4}$	$\frac{3}{64}$ R	70	$\frac{3}{64}$	$\frac{3}{16}\times\frac{1}{8}$	14
$3\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{1}{4}$	$\frac{3}{64}$ R	70	$\frac{3}{64}$	$\frac{3}{16}\times\frac{1}{8}$	16
4	$1\frac{1}{2}$	$1\frac{9}{16}$	$1\frac{1}{4}$	$\frac{1}{16}$ R	65	$\frac{1}{16}$	$\frac{1}{4}\times\frac{5}{32}$	18
$4\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{9}{16}$	$1\frac{1}{4}$	$\frac{1}{16}$ R	65	$\frac{1}{16}$	$\frac{1}{4}\times\frac{5}{32}$	20

FIG. 7.—CYLINDRICAL CUTTERS.

starting lever of the machine, so as to prevent all chance of damage by the feed being changed while the machine was cutting.

Further examination of the machine at this stage showed

TABLE II.—$4\frac{1}{2}$*in. High-speed Cutter,* 10 *Teeth,* 2*in. Hole. Milling Cast-iron Block* 8*in. wide at* 60 *turns* = 70*ft. per minute.*

(Power required to run motor and machine light ·7 net H.P. has been deducted from the recorded H.P.'s to give the figures in the Table.)

Depth of Cut.	Feed Measured.	Net H.P.	Metal Removed. Cubic Ins. per min.	Metal Removed. Cubic Ins. per H.P. min.
·24	$17\frac{5}{8}$	20·3	33·80	1·66
·25	$17\frac{1}{2}$	23·0	35·00	1·52
·26	$17\frac{3}{8}$	26·1	36·15	1·38
·28	$17\frac{3}{16}$	34·6	38·52	1·11
·30	$13\frac{7}{8}$	23·7	33·30	1·40
·32	$13\frac{1}{4}$	29·6	33·92	1·15
·34	$11\frac{5}{8}$	24·9	31·55	1·27
·36	$11\frac{1}{2}$	27·3	33·12	1·21
·375	$13\frac{1}{2}$	22·8	40·50	1·77
·40	$11\frac{3}{16}$	27·3	35·84	1·32
·42	$11\frac{3}{8}$	26·1	38·22	1·46
·44	$9\frac{1}{8}$	23·7	32·12	1·35
·46	$9\frac{1}{16}$	24·9	33·34	1·32
·48	$9\frac{3}{16}$	27·3	35·33	1·29
·50	$9\frac{1}{4}$	30·8	37·00	1·20
·55	$7\frac{1}{2}$	28·6	33·00	1·15
·60	$6\frac{3}{16}$	23·7	29·76	1·25
·625	$9\frac{3}{16}$	24·9	45·93	1·84
·650	$9\frac{1}{4}$	30·8	48·10	1·56
·70	$7\frac{7}{16}$	35·1	41·60	1·19
·75	$6\frac{3}{16}$	28·6	38·80	1·35
·80	$6\frac{1}{16}$	29·6	38·79	1·31
·85	$4\frac{7}{8}$	27·3	33·15	1·21
·90	$4\frac{15}{16}$	29·6	35·54	1·20
·95	$4\frac{3}{4}$	35·1	36·10	1·03
1	4	27·3	32·00	1·17
1·05	$3\frac{7}{8}$	37·1	32·54	·86
1·1	$3\frac{5}{16}$	28·6	29·04	1·02

Table II. shows the results of the tests on cast iron using the $4\frac{1}{2}$in. cutter, and Table III. the corresponding results on mild steel.

that the phosphor-bronze bearings supporting the feed pulleys had worn considerably, and ball bearings were substituted for them with satisfactory results. Other defects came to light during the preliminary tests, such as lubrication troubles, difficulties of manufacture, erection, &c., and alterations were freely made to remedy them, but the incidents described have been selected for description in order to show the kind of defects which are discovered by experimental work of this nature, and in themselves form ample justification for the time, trouble, and expense involved in making the tests. Some of the alterations had to be made in a somewhat make-

TABLE III.—$4\frac{1}{2}$*in. High-speed Cutter,* 10 *Teeth,* 2*in. Hole. Milling Mild-steel Block* 8*in. wide at* 60 *Turns* = 70*ft. per minute.*

(Power required to run motor and machine light ·7 net H.P. has been deducted from the recorded H.P.'s to give the figures in the Table.)

Depth of Cut.	Feed Measured.	Net H.P.	Metal Removed. Cubic Ins. per min.	Metal Removed. Cubic Ins. per H.P. min.
·24	$11\frac{3}{8}$	30·8	21·84	71
·25	$10\frac{7}{8}$	29·6	21·75	·73
·26	$11\frac{1}{8}$	39·8	23·14	·58
·28	$9\frac{1}{8}$	28·6	20·44	·71
·30	$9\frac{1}{32}$	29·6	21·67	·73
·32	$8\frac{7}{8}$	30·8	22·72	·74
·34	$8\frac{15}{16}$	42·1	24·31	·58
·36	$7\frac{5}{16}$	30·8	21·06	·68
·375	$7\frac{1}{8}$	28·6	21·37	·74
·38	$6\frac{3}{4}$	30·8	20·52	·67
·40	$6\frac{1}{16}$	27·3	19·40	·71
·42	6	29·6	20·16	·68
·44	5	24·9	17·60	·71
·46	5	27·3	18·40	·67
·48	$4\frac{15}{16}$	28·6	18·96	·66
·50	$4\frac{15}{16}$	30·1	19·75	·66
·55	$4\frac{7}{8}$	30·8	21·45	·69
·60	$4\frac{13}{16}$	37·1	23·10	·62
·625	$3\frac{15}{16}$	29·0	19·68	·68
·70	$3\frac{15}{16}$	30·8	22·05	·71
·75	$3\frac{1}{4}$	28·6	19·50	·68
·80	$3\frac{1}{4}$	32·0	20·80	·65
·85	$2\frac{5}{8}$	26·1	17·85	·68
·90	$2\frac{9}{16}$	30·8	18·45	·60
·95	$2\frac{1}{8}$	24·9	16·15	·65
1	$2\frac{1}{8}$	29·6	17·00	·57
1·05	$2\frac{1}{16}$	24·9	17·32	·69
1·1	$2\frac{1}{16}$	28·6	18·15	·64

shift manner on the experimental machine, but they were all properly incorporated in the design of subsequent machines.

The cutter finally used in the recorded tests was $4\frac{1}{2}$in. diam., 9in. long, made of high-speed steel. It had 10 teeth and the angle of spiral was $26\frac{3}{4}°$. The diameter of the arbor was 2in. Fig. 7 gives particulars of a range of such cutters suitable for heavy roughing work, and also of the corresponding fine pitch cutters used for light milling.

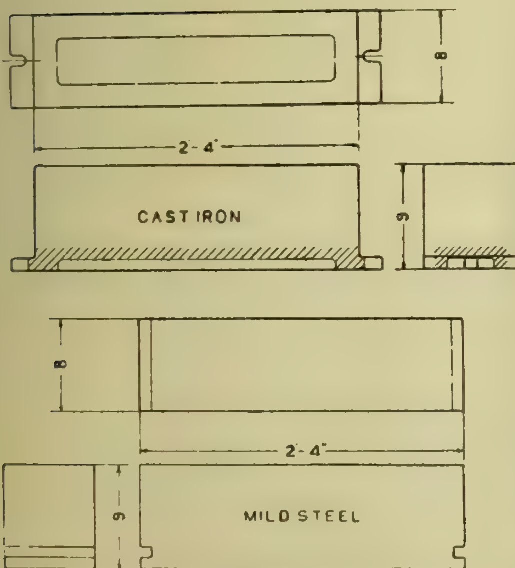


FIG. 8.

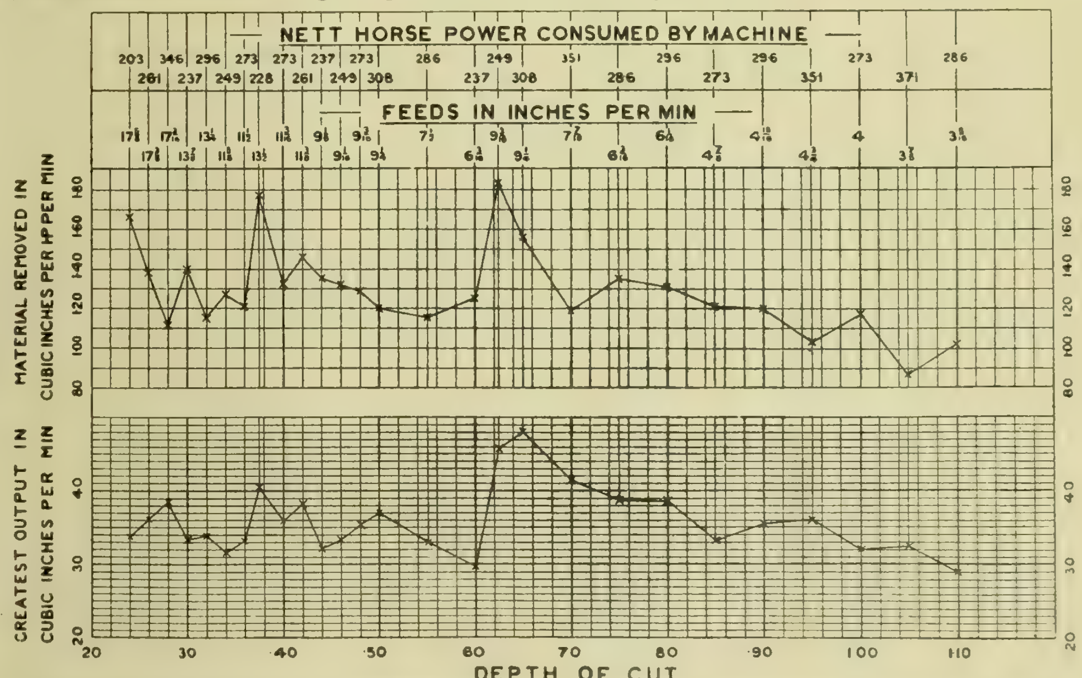


FIG. 9.—OUTPUT CURVES FOR $4\frac{1}{2}$IN. DIAMETER COARSE PITCH CYLINDRICAL CUTTER, MILLING CAST IRON 8IN. WIDE.

The test blocks, made of cast iron and mild steel, were 8in. wide and 2ft. 4in. long, and are shown by Fig. 8. The following are the test figures for both materials.

Cast-iron Test Blocks.

Transverse breaking load on 1in. square bar 12in. between supports	2,520lbs.
Hardness number—Brinell test	254.

Mild Steel Test Blocks.

Maximum tensile stress	26 tons.
Elastic stress...	15 tons.
Elongation—per cent.	31.

As a result of the preliminary experiments it was decided to run the cutter at a speed of 60 turns per minute, equal to just over 70ft. per minute, for all the tests on both cast iron and mild steel. It is possible that higher speeds might have been used on the light cuts and lower on the heavy cuts, but, judging by the preliminary experiments, it did not appear that much would be gained by changing the speed, and it was certain that the introduction of another variable would complicate the results and render generalisation difficult, unless a much greater number of tests could have been made than time permitted.

When taking the various cuts the actual feed of the work was measured by a scale, and was generally found to be rather less than indicated by the feed dial of the machine, owing to the motor slowing down slightly under load, due doubtless to the compound winding. As the feeds were actually measured, however, they gave correct records of the metal removed by each cut.

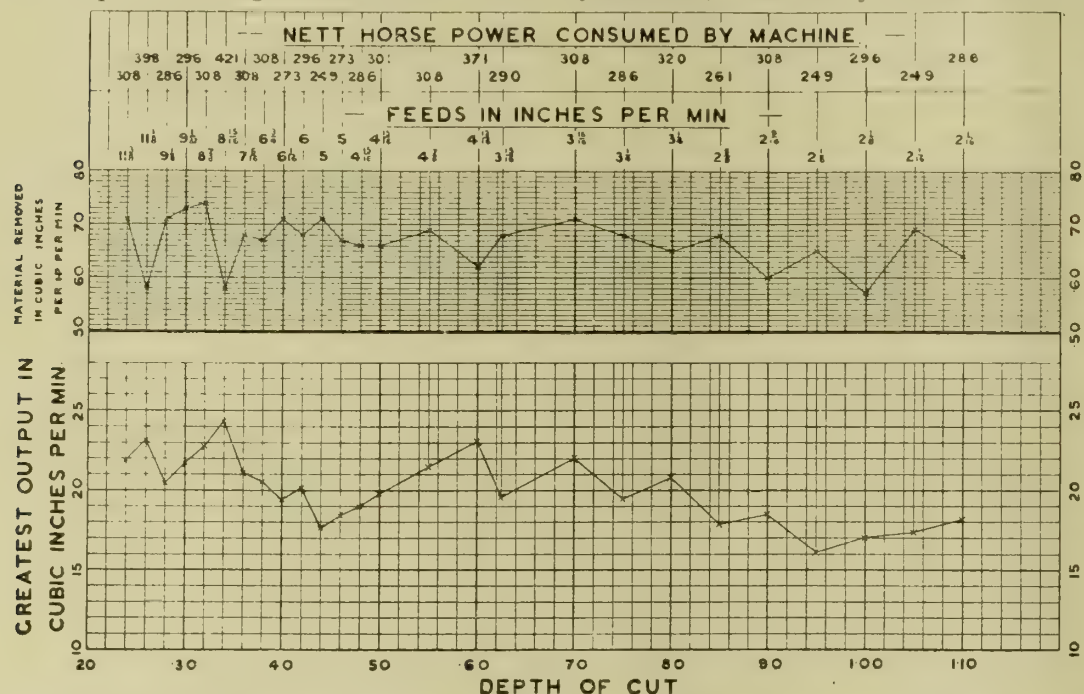


Fig. 10.—Output Curves for 4½in. Diameter Coarse Pitch Cylindrical Cutter, milling mild steel 8in. wide.

The method adopted for making the tests was to begin with the quickest feed provided by the machine, and to take a series of trial cuts until the deepest cut possible was reached, rejecting any cut that caused the belt to slip, or that seemed to be in any other way too much for the machine. The next lower feed was then taken and the depth of cut further increased, and so on until the maximum safe depth of cut possible with each feed was reached. The cutter was carefully watched to determine when it required to be resharpened, which was only twice during the cast iron tests, and not at all during the mild steel tests.

Figs. 9 and 10 give the results in plotted form for the convenience of those who prefer diagrams to tables. The three high points in the upper part of Fig. 9 clearly show the temporary increase of efficiency of the cutter after being sharpened. It might not be unreasonable to expect that the tests would provide formulæ from which the performances of the machine and cutter could be calculated on other cuts than those actually taken. It does not seem to be possible, however, to formulate anything in the nature of an accurate law in a scientific sense, but the figures do nevertheless indicate very clearly certain limits of output, power, and efficiency which are of very great use for comparison with other experiments, and for forming a basis for future tests of other and probably still more efficient machines.

As a result of the whole series of tests it may be said that, on material of the kind used for the tests, certain broad generalisations can be made, such as:—

(1) A 5in. double belt driving a 16in. pulley at a speed of 400 per minute (100,531 sq. in. of belt per minute) geared to drive a 4½in. cutter at 70ft. per minute is able to remove as much as 48·1 cub. in. of cast iron, and 24·31 cub. in. of mild steel in a minute.

(2) 2,090 sq. in. of double belt passing over a pulley in a minute will remove 1 cub. in. of cast iron on a milling machine.

(3) 4,135 sq. in. of double belt passing over a pulley in a minute will remove 1 cub. in. of mild steel on a milling machine.

(4) A 4½in. cutter on a 2in. arbor running at 70ft. per minute is capable of removing at least 3·63 cub. in., and possibly as much as 6·01 cub. in. of cast iron, and at least 2·125 cub. in., and possibly as much as 3·03 cub. in. of mild steel per minute for each inch of width up to 8in., and at any depth of cut from ·24in. up to 1·1in.

These figures are taken from the maximum and minimum outputs of the various test cuts, and should be reliable for comparison if the machine on which the work is done is reasonably efficient and has enough power and strength. The figures confirm a conclusion arrived at by the author some years ago, and published in an article in "The Engineer" of March 19th, 1909, page 286, that:—

(5) A milling machine when on maximum output will remove about twice as much cast iron as mild steel per minute, the maximum figures in the present tests being 48·1 and 24·31 respectively.

(6) 1 h.p. is able to remove as much as 1·84 cub. in. of cast iron, or ·74 cub. in. of mild steel in a minute.

In the "Engineer" article, which dealt with a series of tests of a smaller machine of cone pulley type, the maximum metal removed per horse-power minute was 1·52 cub. in. of cast iron, and ·71 cub. in. of mild steel, figures which seem to indicate that:—

(7) An all-geared machine need not be any less and can be considerably more efficient than a cone pulley machine.

The maximum power transmitted by the 5in. belt driving the 16in. pulley at 400 turns per minute was 42·8 h.p. and the minimum 21 h.p., when taking the recorded cuts, the effective driving tensions working out at about 168lbs. and 82lbs. per inch of width. From this it can be said that:—

(8) A double belt can be made to drive at an effective pull of as much as 168lbs. per inch of width when testing a machine for maximum output.

These tensions are of course higher than would be good practice for regular work, but are justified by the fact that the machine was tested to a point far in excess of what would be expected from it in the way of ordinary output. At the same time, both the belt and the machine accomplished the work without suffering in any way, showing that there was an ample reserve of strength. As a matter of fact, for ordinary work a motor of 15 h.p. or 20 h.p. is considered to be large enough for the machine, although a 40 h.p. motor could be safely used where heavy cuts were the rule rather than the exception.

In the foregoing tests material of known quality has been milled with a cutter of known size, type, design, and material. The speed was known, also the gear ratio, and the belt power. The horse-power consumed was known and the amount of cut that could be taken. The information is of a definite nature,

and should be applicable to any equally efficient machine. The tests should therefore give the milling machine user some data from which to judge what his machines and cutters may be made to do.

From the maker's point of view the experiments as a whole were eminently satisfactory, inasmuch as vital defects were discovered before a single machine was sold, and to the purchaser the knowledge that a machine had passed through such a severe ordeal cannot be otherwise than reassuring.

REVERSIBLE UNITS FOR TURBO-PUMPS, BLOWERS, AND AIR COMPRESSORS.

To enable, in the case of turbo-pumps, blowers, and air compressors, the same casings, bearings, rotors, steam nozzles, vanes or blades, and shaft to be employed for both right and left hand units Messrs. G. & J. Weir, Ltd., Cathcart, Glasgow, and Mr. J. Petermöller have recently patented the arrangement illustrated herewith, which shows a unit consisting of a steam turbine driving a centrifugal pump having a tangential and horizontal delivery, the turbine rotor consisting of three wheels mounted directly on the shaft, and the shaft being provided with a bearing between the turbine and the pump rotors, and a bearing beyond each rotor. The turbine casing is constructed in two parts B, C, the division being in a horizontal plane which passes through the axis of the shaft. The shaft bearings D and E are constructed integrally with the lower part C of the turbine casing, while the steam connection F and the exhaust connection G are arranged on the upper part B and vertically above the axis of the machine. The pump casing also is constructed in two parts—an upper part H and a lower part K—and the part K and the outside bearing M at the pump end are arranged so that the bearing can be attached to either end of the casing. The shaft is constructed in two parts O and O[1], of which the

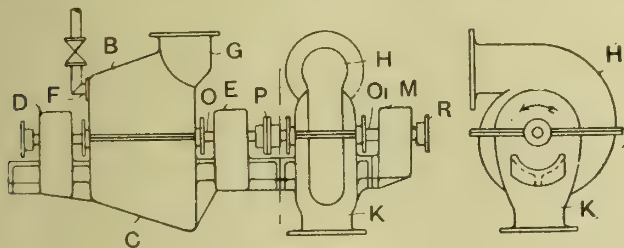


Fig. 1.

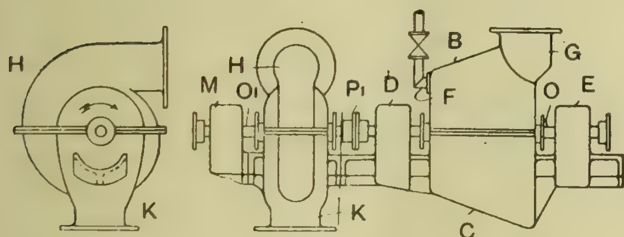


Fig. 2.
Reversible Units for Turbo-Pumps.

part O carries the turbine wheels and the part O[1] the pump impeller. The two parts are connected together at P in Fig. 1 and at P[1] in Fig. 2.

With this construction, in order to convert a left-hand unit, Fig. 1, into a right-hand unit, Fig. 2, the two parts of the shaft are disconnected from each other at P, the pump brought over to the other end of the turbine, and the bearing M connected to the other end of the pump casing, so that it again acts as a pump end bearing. The part O[1] of the shaft is moved axially from right to left with respect to the pump rotor and casing so as to accommodate the bearing M at its other end, and what were previously the free ends of the two parts of the shaft are connected together at P[1]. The bearing D now becomes the intermediate bearing, and the bearing E becomes the turbine end bearing. The direction of rotation of the shaft and rotors remains unchanged.

The arrangement described may be modified by reversing either or both portions of the shaft when converting from a left-hand to a right-hand unit. For example, if the part O[1] of the shaft is adapted to be reversed (*i.e.*, turned end for end), then only one end of this shaft need be arranged for coupling to the other portion of the shaft. The flange R, Fig. 1, can therefore be omitted, and no provision need be made for attaching a flange to this end of the shaft O[1], which will always be the free end. The pump impeller can always be slipped on to the shaft at this free end, and this may be a matter of convenience in some cases, as the shaft may be tapered or may be provided with a flange or collar. The same remarks apply to the portion O of the shaft. Moreover, flanges, although shown in Figs. 1 and 2, are not necessary at the free ends of the shafts even when neither part of the shaft is reversible. Only two flanges in all need be provided, these being employed only on the adjacent ends of the two parts of the shaft, and each flange being unfixed from one end and fixed to the other end of its shaft when the unit is being changed from left-hand to right-hand or vice versâ. The arrangement may be further modified by constructing the shaft all in one piece, which will then be stripped of its rotors when a unit is being converted from left-hand to right-hand or vice versâ. The shaft may also, if desired, be reversed (*i.e.*, turned end for end) when the unit is being converted. A number of further modifications are described and illustrated in the patent specification, but the example illustrated is sufficient to indicate the nature of the improvements.

THE BRITISH FIRE-PREVENTION COMMITTEE.

We have received from this committee a pamphlet setting forth the aims and the admirable research work it has accomplished since its constitution in 1897. Expressed in popular language, the committee's work on the very technical, but eminently humanitarian, subject of fire prevention—which means so much for the safety of life and property—may be said to be divided under five headings, namely:—

(1) Conducting investigations and preparing reports thereon.

(2) Compiling records and issuing publications.

(3) Advising on technical matters and making suggestions as to preventive legislation.

(4) Preparing warnings and cautions and distributing them.

(5) Popularising simple safeguards and calling attention to common forms of negligence.

The funds of the committee are derived from subscriptions, sales of reports, and on one occasion a small Treasury grant of £150. These sources of revenue have, however, not sufficed to carry out the work undertaken by the committee, which necessitated the establishment and upkeep of a fully-equipped testing station. There have been frequent substantial deficits on the annual accounts, whilst the heavy capital outlay for the testing equipment has had to be met by special effort. The individual members of the executive, besides rendering considerable services and meeting all "out of pocket" expenses in connection with the work—which at times are substantial in amount—have actually had to put considerable funds at the disposal of the committee. They have, as a matter of fact, done so to the extent of over £4,000. Without this sum—£4,000—a sum which might well have been provided by the State, in part or whole, in some form of annual grant, supplemented, say, by contributions from the other public authorities concerned—the entire work of the committee would have been impossible. This condition of affairs, the committee urged, should now cease, inasmuch as the work of the committee is of an imperial character, and it is trusted the State and others concerned will in future contribute liberally to the committee's humanitarian efforts.

Case-hardening. — At a meeting of the Scientific Society of the Glasgow Royal Technical College on Saturday last Mr. David Keachie read a paper on "Case-hardening." Mr. Keachie dealt with the materials, plant, and apparatus necessary for the hardening process. The actions taking place in the process were also referred to by the lecturer. Pyrometers used to measure the temperatures in hardening furnaces were shown and described, and also the scleroscope—an apparatus employed to determine the hardness of the casing. A number of specimens to show various temperature and quenching effects were shown.

A NEW CYCLE OF OPERATIONS IN REFRIGERATING MACHINES.

IN a paper entitled "A Contribution to the Theory of Refrigerating Machines," presented before the Institution of Mechanical Engineers on November 22nd, Dr. John H. Grindley describes a new cycle of operations in refrigerating machines which indicates that increased performances can be obtained from such machines.

Fig. 1 shows a τ-ϕ (temporary-entropy) diagram for CO_2 giving a particular cycle of operations for the refrigerant as follows: Let A B C be the boundary line for the liquid and dry vapour of CO_2 drawn in the usual manner, and let the lines A C and B E be drawn at the lower and upper temperatures t_1 and t_2 at which the refrigerant takes in its heat and, in the main, rejects its heat respectively. Further, assume the compression to be dry and adiabatic.

Starting with the liquid in condition represented by the point B just before freely expanding it through the throttle, we should by using an expansion cylinder and expanding the liquid to the lower temperature adiabatically obtain the refrigerant in condition represented by D; but, owing to the abolition of the expansion cylinder, the actual condition of the refrigerant after free expansion is represented by D_1, the area under D D_1 (D $D_1 M_1$M) being equal to the area A_1B D, the curve A_1B being a constant pressure line through B. The refrigerant now takes up heat represented by the area D_1C N M_1 until it becomes dry vapour represented by point C, and it is then compressed adiabatically as represented by C G until the pressure reaches that given by the constant pressure line E G drawn through E, after which it is condensed back to its original state represented by B.

This is the usual cycle and diagram discussed in the text books, and it is there shown that the work done (W) in the compressor is represented (in heat units) by the area A B G C A and the refrigerating effect (R) by the area D_1C N M_1, the ratio $\frac{R}{W}$ of these two areas giving (η) the coefficient of performance.

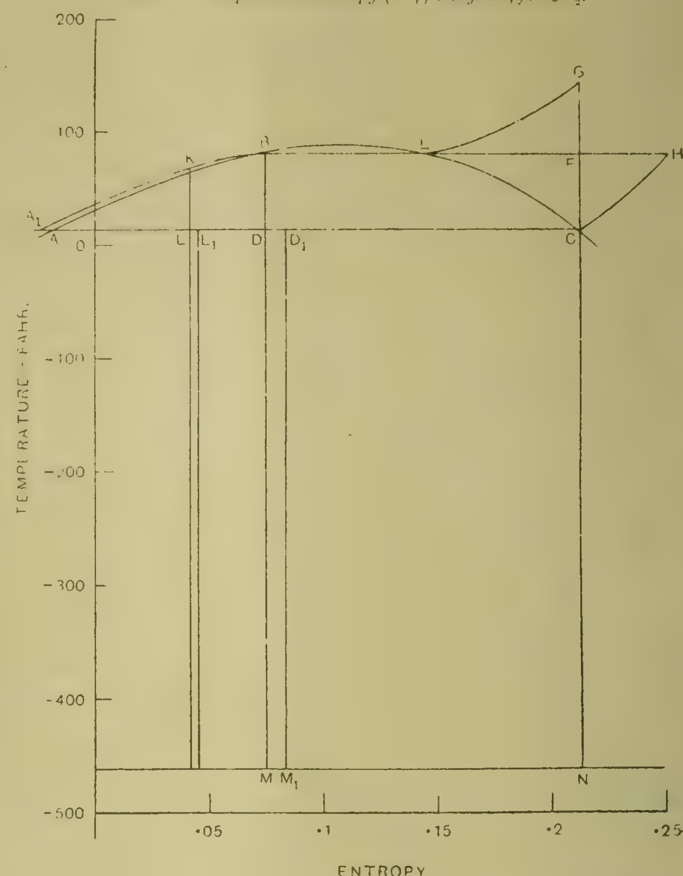
It is a well-appreciated fact when using CO_2 that under-cooling the liquid before freely expanding it shows a marked improvement in the performance of the machine; and it occurred to the author that the following alterations in the cycle would show some gain in the performance.

The cycle of operations in actual machines being a continuous one, let the relatively hot liquid in condition represented by B, Fig. 1, before passing the throttle be passed through a narrow tube surrounded by a second larger tube through which the cold dry vapour in condition represented by C before compression passes, the liquid and vapour flowing in opposite directions so that the transfer of heat can be effected in as near as possible a regenerative manner. By doing this the liquid could be cooled down considerably before being freely expanded, while the vapour would have become superheated to practically the upper temperature t_2. If the specific heats of the liquid and vapour were equal, the liquid could be practically cooled to the lower temperature t_1 while the dry vapour became superheated to t_2. In reality, owing to the difference in the specific heats, the dry vapour takes up heat as represented by the area under C H, Fig. 1, which is a constant pressure line through C, and the liquid has been cooled to a temperature represented by K, where the whole area under B K is equal to the area under C H, one area representing the heat given up by the liquid and the other that taken in by the vapour.

Now, the condition of the gas being represented by H, let the cylinder be well jacketed by condensing water so as to produce compression as nearly as possible isothermal. The compression operation would then be represented by the constant temperature line H E, after which the vapour is condensed and returned to condition B where in turn it could be undercooled to K. The free expansion operation would then bring the liquid into condition represented by L_1, where area A K L = area under L L_1. The cycle of operations is then represented by K L_1C H B K. It involves: (1) Undercooling of the liquid before free expansion; (2) superheating of the vapour before compression; (3) isothermal compression.

Comparing this cycle with the usual cycle of operations, we find that the work done in the compressor (W) is represented for the latter cycle by A C G B A and for the new cycle by A C H B A. The difference between these areas resolves itself into the difference between the triangular areas E F G and F C H, a difference obviously very small, and we may take the work done to be the same in the two cycles. As regards the refrigerating effect (R) the gain is at once obvious, the area under L_1C representing the new refrigerating effect

FIG. 1.—*Temperature Entropy (τ - ϕ) Diagram, for CO_2.*



as against the area under D_1C for the old cycle. The ratio $\frac{L_1D_1}{D_1C}$ represents the fractional increase in R and the area under L_1D_1 the net gain in R.

To give actual figures for the values of W and R in the two cycles the author has calculated in British thermal units the numbers given in Table I., the suffixes 1 and 2 distinguishing the old and new cycles respectively.

TABLE I.

Upper Pressure.	Temp. Limits.		W_1.	W_2.	R_1.	R_2.	$\frac{R_1}{W_1}=\eta_1$	$\frac{R_2}{W_2}=\eta_2$	Per cent. Increase in Performance.
Lb. per sq. in.	°F.	°F.							
800	20	65·7	10·9	11·0	78·9	93·3	7·24	8·49	17
800	10	65·7	14·2	14·1	79·4	95·7	5·59	6·77	21
800	0	65·7	17·2	17·5	79·5	97·6	4·62	5·58	21
1,000	20	82·5	15·0	14·5	59·4	79·5	3·96	5·48	38
1,000	10	82·5	18·7	17·9	59·9	81 8	3·20	4·57	43
1,000	0	82·5	21·3	21·5	60·0	83·6	2 75	3·89	41
1,200	20	90·0	18·4	16·9	59·2	79·8	3·22	4 73	47
1,200	10	90·0	22·4	20·2	59·7	81·9	2·66	4·06	53
1,200	0	90·0	26·3	23·9	59·8	83·6	2·27	3·50	53

The figures in the last column lead to the conclusion that large increases in the performance of vapour-compression machines might be expected to follow from the adoption of the new cycle, especially when using condensing water at high temperatures. The new cycle would therefore be expected to give the best improvements when used in machines working in hot countries.

For NH_3 machines an examination of the τ-ϕ diagrams for the old and new cycles would show that increases in performance would also follow from the adoption of the new cycle, but they may be more difficult of realisation in practice.

Assuming the compressions to be strictly adiabatic or isothermal as the case may be, the calculations on the τ-ϕ diagram would show a gain in performance sometimes as high as 20 per cent., part of which should undoubtedly be obtainable in practice.

The working of the proposed cycle involves two additions to the usual machines, first, an efficient water jacket to the compression cylinder so that the compression may be as nearly as possible isothermal, and second, a simple arrangement of inner and outer tubes as described, by which the cold vapour before compression can take up from the relatively hot liquid before passing through the expansion valve as much of its heat as possible, the transfer being accomplished in as nearly as possible a regenerative manner.

MECHANICAL HANDLING OF COAL FOR BRITISH LOCOMOTIVES.*

BY CHARLES JOHN BOWEN COOKE, M.INST.C.E.

OWING to the growth of traffic and the heavier loads which have to be hauled at the present time, it has been found expedient to adopt, at the extensive running-shed of the London and North-western Railway Company at Crewe, some more expeditious method than "man-handling" for loading engines with coal, and after much deliberation the mechanical coal-handling plant described in this paper has been installed. The plant was made by Messrs. Babcock & Wilcox, and is the joint design of the author and that firm.

The points to which careful consideration had to be given were numerous, particular attention being paid to the following: (1) The cheap rate at which coal is at present dealt with by hand. (2) The large size of the coal mined, and the class and size of coal wagons in use in England. (3) The regular supply of coal between colliery and steam shed. (4) The restricted area available, and the high cost of land for extensions and alterations to steam shed yards. (5) The impracticability of an appliance capable of dealing with coal between wagon and tender, wagon and stack, or stack and wagon. (6) The expenditure necessary for installing such a plant. (7) The breakage of coal during the transfer.

With regard to the fifth point, in considering the installation of a plant capable of doing the work required, the various known types of apparatus limited the choice to one or two types, namely: (*a*) That built by certain railway companies abroad, in which the handling of stock and current coal by gravity-bucket, or belt-conveyer, is combined; (*b*) some form of power-driven crane and grab-bucket.

The stock in plants of type (*a*) rarely exceeds 3,000 tons and is situated in bunkers, either underground and immediately under the coaling stage, or above ground and forming part of the coaling stage. In the latter case, coal placed in stock would be handled no less than six times between the colliery and the locomotive tender, with consequent breakage of coal at each stage. It is found that at nearly all depôts in this country where the annual consumption is sufficient to warrant the installation of mechanical handling, the stock coal greatly exceeds 3,000 tons, so that this type of plant appears undesirable.

Regarding type (*b*), a grab bucket is limited in size by the receptacle from which it picks its load, and when working from an ordinary type of English railway wagon, such an appliance becomes anything but economical in its operation. The maximum size which can be usefully worked is about 44 cub. ft. or 1 ton; little margin being then left for steering between the sides of the wagon. Again, a good deal of the efficiency of a grab bucket depends on the drop it gets into the material, but when such material consists of large lumps of coal carried in a wooden truck which is liable to damage, the efficiency of the grab is reduced in an excessive degree.

With regard to the sixth point, consideration of several types of plant showed that a suitable one could not be erected for less than from £5,000 to £6,000 capital expenditure. Such a plant, when handling 450 tons per day or 140,000 tons per annum, with electric current (if available) at about 1d. per unit, would do the work at a cost of about 2d. per ton, including all necessary working charges, &c. Such an expenditure, with such a result, might lead locomotive engineers to the conclusion that, in their case, the experiment was not worth trying, owing to the smaller tonnage dealt with. The consideration of certain inducements might, however, be studied before condemning such a proposition. For instance (1) a mechanical plant, whilst occupying less ground than an old-fashioned coal stage, could deal with nearly double the quantity of coal per annum; (2) there is an economical advantage in coaling as many engines as possible at a point adjacent to the collieries (where coal is cheapest), and in the shortest time possible; (3) the rapidity of coaling might enable a railway company to dispense with an engine or two, or even to refrain from building a similar number, with consequent economy of capital; (4) the release of wagons would probably take place in less than half the time required at present, with consequent increase in earning capacity, and a possible reduction in the cost of shunting in the shed yard.

With regard to the seventh point, the large amount of slack created by the present method of man-handling is perhaps not generally realised, and mechanical plants should be designed with a view to dropping the coal as seldom as possible during its transfer from the wagon to its ultimate receptacle. Further, the height of its fall should be minimised; the coal should be arranged to slide wherever possible; and, when loaded on to a tender, it should be delivered of such a size that no additional breaking by the fireman is required.

The plant at Crewe consists of a wagon tippler, an underground hopper, a tipping tray conveyer, an elevated bunker, and shoots—including calibrating chambers—for discharging coal on to the tenders. The tippler is of mild steel rolled sections, with rings 12ft. diam., and is capable of tipping a wagon in about 5 minutes, when attended by two men. It is driven by a 660-volt direct-current electric motor of 5 h.p. The hopper, constructed of mild steel plates and angles, holds about 20 tons; the coal being fed therefrom by a jigging tray through an adjustable door into a two-roll breaker, where the large lumps are reduced to 8in. cubes. The breaker is belt driven by an independent direct-current electric motor of 10 h.p., which also operates the jigging tray. The coal passes through the breaker to the conveyer trays, which carry it to the overhead storage. The conveyer runs at a speed of 70ft. per minute, and is capable of lifting about 60 tons per hour. The driving gear is situated at the top under the bunker housing, and consists of a 660-volt direct-current electric motor of 9 h.p. All the coal is delivered over the end of the conveyer track, when it has only a fall of about 1ft. on to the inclined shoot which delivers it to the requisite division of the bunker.

The bunkers were designed to hold 300 tons, which is more than enough to coal all engines during the night without the conveyer working, it being possible to send up during the hours of daylight all the coal required, thus saving the double manning of the wagon tippler and conveyer. There is an outlet on either side of each division of the bunker—which is divided into two main parts to give separate storage for about 100 tons of Welsh (soft) coal and 200 tons of "hard" coal—making four outlets in all, so that the tenders can be coaled on both sides at the same time. These outlets are 2ft. by 2ft., and are provided with doors worked by hand. On opening one of the doors coal is permitted to flow out into a calibrating chamber capable of holding 10 cwt., whence it is allowed to slide on to the tender by means of a lever conveniently situated.

The speed of coaling by this plant is quite satisfactory, as much as 6 tons being put on in 3 minutes, as against 5 tons in 15 minutes with the old system under the most favourable circumstances. An ash conveyer has been installed in conjunction with the coaling plant. When an engine has received its coal it draws down to a point a little distance away, where the firebox ashes are raked out by hand on to a sloping plate, which slides the ashes on to a grid (with 4in. mesh) fixed close to the side of the pit. This grid covers a small hopper which feeds the conveyer through a rotary filler. The ashes are then raised and delivered into a wagon standing on an adjoining line. The conveyer, which is of the bucket type, has a capacity of about 15 tons per hour, and is driven by a 3 h.p. direct-current motor. A supply of water is laid on for slaking the hot ashes.

* Abstract of paper read before the Institution of Civil Engineers, November 26th, 1912.

SOME PROBLEMS IN ELECTRICAL ENGINEERING.

At a joint meeting of the Electrical Section of the Western Society of Engineers and the Chicago Section of the American Institute of Electrical Engineers a lecture on "Some Problems in Electrical Engineering" was delivered by Dr. C. P. Steinmetz. There was, he said, a marked tendency in generation toward the concentration of the supply of electrical energy for all uses for a large territory from one system. The large system had economical advantages over numerous small ones. One of its most conspicuous advantages was the possibility of utilisation of the diversity-factor. The price of producing electrical energy depended to a large extent on the load-factor. The station must be such as required by maximum demand, but the income depended on the average demand. The load-factors of most users of electrical energy were relatively poor. Even the factory operating continuously for eight hours created a demand during only one-third of a 24-hour day. However, if a number of users of electrical energy were supplied from the same generating system a better average would result, owing to the diversity-factor of the different loads. Therefore, the more different uses there were for the energy the less would be the cost.

Beyond the advantage of this diversity-factor, which was now obvious, there was, he observed, another diversity-factor, which was of perhaps even greater advantage, though not so apparent to casual inspection. That was the diversity-factor of intelligence. New problems arose with the development of the large system. A central-station system in a city of moderate size might have one or two first-class engineers, but in the large systems, where new electrical problems arose, and also mechanical problems and problems of administration and finance, nô man could be an expert in all the varied activities of the company. And so there would be found attached to the system the highest authorities in the various branches required for the most efficient operation of the system. The men in charge of such a concentrated system of production should not be merely up to date, but should be, in fact, ahead of date, *i.e.*, they should solve in advance the problems which would arise. Here was an advantage of the greater system probably much more important than that of better load-factor. It might be called the diversity-factor of intelligence.

When electrical energy was first applied to the operation of machinery it was generated at the mill or factory where it was used. However, the factory was specialised for its purposes as a factory. Its management was efficient in cotton spinning, say, but not in the operation of an electric plant, and unless the circumstances were exceptional could not be so efficient in the specialised detail of producing energy for use in its own work. That accounted for the fact that it was usually found more economical for the cotton mill to purchase electrical energy from central stations which were specialised for the purpose of producing it.

As the generation of electrical energy was being concentrated in larger system units at the present time, he asked what would be the future of the industry. Evidently the territories served would increase in size. Big cities had an advantage in this respect, of course, because they had as a nucleus their own large demand. The outcome must be the replacement of village and small city generating plants by the sub-stations of big systems. Old machinery would thus be replaced by modern types. These big generating systems would tend to approach one another; then would come, no doubt, an era of co-operation, and it was not too much to expect a network of energy-transmission wires covering the country, just as the railroads did to-day. Energy would be transmitted in the one case as freight was transported in the other. It might be possible, said Dr. Steinmetz, to go a little further and estimate how such a development would take place. The local distribution system would remain the same probably as now, viz., a 3-wire system for either direct current or alternating current. This system of distribution had stood the test of over a quarter of a century and would probably remain. The distributing sub-stations would probably be supplied over 2,200-volt alternating-current feeders, the energy being transformed to 600-volt direct current for railway operation or 220-volt direct current or alternating current for various forms of commercial service. Beyond this would probably be an intermediate system of feeders around 10,000 volts which might be styled transmission feeders. These, like the 2,200-volt distribution, would be laid underground in cities and carried as overhead lines in the country. For greater distances 20,000-volt or 30,000-volt distribution lines would be supplied, and these, too, would be underground in city districts. In this class of transmission in overhead work it was probable that the highest voltage would be adopted which did not require special precautions in installation, say, about 30,000 volts. But there would be flexibility in these transmission feeders, and some would operate at as high as 60,000 volts. In addition to these there must be great trunk lines for the transmission of electrical energy radiating from the big generating centres and comparable to the trunk lines of railways. These would be built for the highest practicable operating electromotive force—probably between 150,000 volts and 200,000 volts—or, in other words, at the limit imposed by the dissipation of energy into the atmosphere through the corona effect.

Considering this whole great system of generation, transmission, and distribution, it might, he continued, be interesting to speculate on its efficiency as a whole. There would be at least two transformations of energy and, figuring on these and the line losses, it was probable that the average loss between the generator terminals and the customers' meters, possibly 100 miles away, would be less than 10 per cent. The exceptionally high-voltage transmission lines spoken of would probably not carry large amounts of energy. They would rather be tie lines between two great city systems, and in general only a moderate degree of energy would flow through them. They would be for emergency connections between two great systems and for use in helping out in cases of peak-load, contributing to the reliability of operation and serving as a sort of insurance.

At present the industries demanded energy usually for eight hours a day. If industries could be developed to utilise energy in the other 16 hours the problem would be solved, and that, in fact, was the great problem of the electrical engineers of the future. Old industries could not of themselves be expected to change a great deal, although something could be done. It might appear rather far-fetched to expect industries to adapt their conditions to entirely different hours to avail themselves of cheap energy. Still, some large industries had adapted themselves to such an arrangement. The steam engine, for instance, had encouraged a uniform load in factory production. If one looked around without prejudice he would be astonished tc find how many industries were affected vitally by the characteristics of the motor service available. Our methods were really the result of the characteristics of the tools we used. It was difficult to understand that new forms of motor service need not be adapted to old industrial methods, but rather that the industrial methods should be re-arranged to use the service to best advantage. An industry utilising electricity from a big national interconnected system must be adapted to the new conditions to get maximum economy.

In his concluding remarks Dr. Steinmetz referred briefly to the utilisation of water powers and their relation to the unified system of generation, transmission, and distribution which he had assumed. Water power was, he said, cheap, but not very reliable. Some uses of energy required absolute reliability, as in the central-station service of a big city. Here the use of water power was out of the question, ordinarily, without a continuous steam reserve. But in some cases the interruptions to service were not so serious. As an illustration he took the case of an electrochemical or electrometallurgical industry taking 100,000 kw. Here, where the use of power was very large and the number of men employed comparatively small, it might be profitable to shut down the entire plant, even with a large investment, for two months in the summer, giving workmen a vacation with full pay, by reason of the economies effected in even a very slight reduction in the cost of each unit of electrical energy purchased. In this case the use of water power, even with a long interruption (where the interruption might be anticipated and provided for), was decidedly advantageous. The whole problem of utilising water power required very careful consideration, and that was true of all the relations of the production of energy and its utilisation by industries. The specialist of the electrical industry was a great intermediary in this matter of energy production and utilisation. He must go into the other industries and reorganise them to adapt themselves to the motive-power characteristics of the future day. The great problem was to reorganise the industries to use advantageously the energy made available by electricity. That problem, said Dr. Steinmetz in closing, was still before us.

INTERNATIONAL ENGINEERING AND MACHINERY EXHIBITION, OLYMPIA.—VIII.

Messrs. J. Parkinson & Son, of Shipley, Yorkshire, perhaps best known to our readers as makers of the "Perfect" vice, had a large and interesting exhibit of machine tools. As representative of their manufactures, they exhibited two lathes, three horizontal spindle milling machines, one universal milling machine, one thread milling machine, one "Sunderland" gear planer, a machine for sharpening the "Sunderland" cutters, and jigs for testing spur, spiral, and bevel gears. Most of these machines were in motion, and five of them were arranged for direct motor drive.

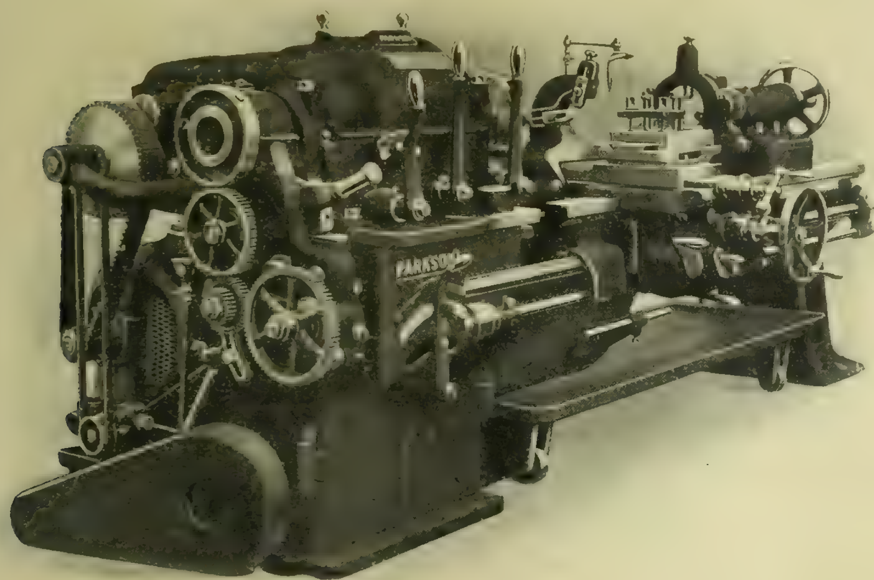


FIG. 1. 9IN. CENTRE "PARKSON" LATHE WITH MOTOR DRIVE.

Of the two lathes shown, viz., a 7½in. and 9in. centre, we select the 9in. for special description. This is illustrated in Figs. 1, 2, and 3, Fig. 1 being a general view, Fig. 2 a view of the tailstock showing the thrust panel and rack, and Fig. 3 the all-gear head with cover removed. As will be seen, it is a massively-built tool, and the motor, being mounted on a bracket behind the cabinet standard, makes a compact arrangement. The headstock has 16 rates of spindle speed, obtained by sliding gears and clutches, and any speed may be obtained without stopping the lathe. The first motion shaft is designed to run at 335 revs. per minute, and when arranged for belt drive (as shown in Fig. 3) instead of motor drive, as in Fig. 1, it carries a pulley 12in. diam. and 5in. wide.

The tailstock, as shown in Fig. 2, has a spindle of the "through" type, and is arranged with cross adjustment, and carries a pawl which engages a rack with buttress teeth between the shears of the bed, and thus prevents the tailstock thrusting back under a heavy cut.

The sliding and surfacing feeds are engaged and disengaged by "lift and drop" worm, but a feed selector makes it impossible to engage two feeds at the same time. The feed selector is a sliding gear keyed to a revolving shaft, at the front end of which is a knob, by means of which the gear may be moved out of mesh with the train of gears for the sliding feed, into mesh with the gears for the surfacing feed, or vice versâ. The sliding feed has automatic trip, and may, we understand, when desired, be arranged with multiple stops, the advantage of this being obvious for repetition work.

Another feature of interest at the show would be found in the gear-testing jigs for spur, spiral, and bevel gears. These are very sensitive, and will be of great value to those wishing to locate gear troubles. Wheels are intended to be tested either in pairs or compared with a master gear. In either case, one of the pair is mounted in a fixed position and the other on a movable carriage; two methods of holding the gears in mesh are provided, one for ascertaining how the gears "run" when the centres are fixed and the other to ascertain the effect produced by eccentricity of gears, defective teeth, incorrect form, or errors in sizing and spacing. Each of these defects causes movement of the carriage when the gears are rotated in close mesh, the movement being indicated by an extremely sensitive dial indicator.

An additional indicator, which is also a recorder, is shown applied to the bevel jig which we have pleasure in illustrating in Fig. 4. This traces a line on a chart, and thus makes a permanent record of the particular gears.

The steady encroachment of the milling machine on a class of work for which the screw-cutting lathe formerly held the monopoly is emphasized by the thread milling machine. This machine (shown in Fig. 5), although capable of doing external threading within certain limits, finds its greatest scope in internal threads, for which it has been specially designed. In some respects, owing doubtless to the longer arc of contact the cutter makes with the internal than with the external work, internal milling puts more severe stresses on the machine, particularly on the mechanism which drives the cutter, than does external milling, and in the design of the machine under notice, attention has been given to making the machine equal to the demands of internal work.

There are, of course, limitations to the scope of a machine of this kind; for example, the smallest hole that may be thread milled is fixed by the smallest size of practicable cutter, plus the necessary clearances. In this machine the limit is fixed at 1in. diam. There is also a limit for depth of hole or length of thread, but within its fair field it is claimed that the machine will produce threads faster than the screw-cutting lathe, a claim fully justified by its performance at Olympia, where steel rings with holes 3in. diam. and 1in. wide, having 12 threads per inch, were threaded in 1½ minutes with excellent results. But even if the lathe

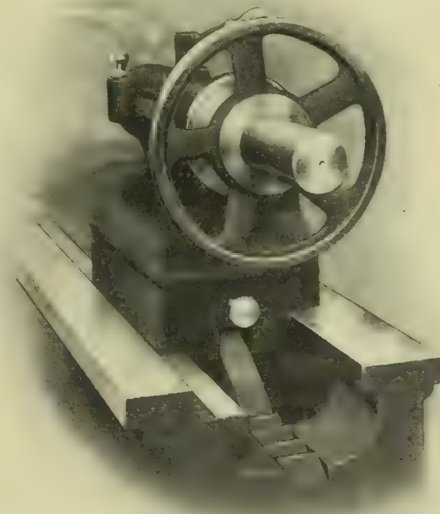


FIG. 2.—9IN. CENTRE "PARKSON" LATHE. TAILSTOCK WITH THRUST PANEL AND RACK.

time were less than this, the milling process would still have the advantage of securing closer uniformity and interchangeability. That tapping also may be quicker than milling is not likely to be disputed, but milling is more accurate and sizes are more easily maintained; the cutters are cheaper than taps, and a small number of cutters will cover a very wide range of holes.

For fine threads and pieces such as lock nuts, cutters having a number of threads and longer than the part to be threaded by at least one thread may be used. These cutters have the appearance of hobs; the teeth, however, are not cut spiral, but circular, so that when the whole width of the cutter has been fed to depth the rotary feed of the work and longitudinal feed of the cutter may be engaged, with the result that on the completion of one revolution the cutter has advanced one thread or pitch, and there is 1in. or 1¼in. width of finished thread, as the case may be, according to the width of the cutter. It is obvious that a cutter with a single row of teeth may be used, but in such case the work must make more than one revolution, and the time occupied be accordingly increased.

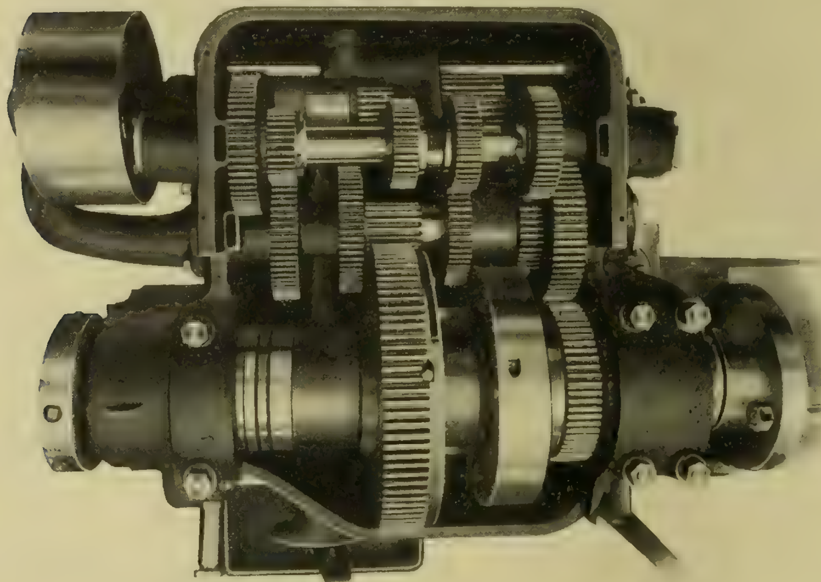


FIG. 3.—9IN. CENTRE "PARKSON" LATHE. ALL GEARED HEADSTOCK, WITH COVER REMOVED.

As will be seen, the headstock carries a large-diameter spindle which may be rotated at two speeds by means of worm gears, the change from one speed to the other being made by means of a lever. The object of rotating the spindle at two speeds is to give a faster speed than that used for milling, the faster speed being useful when indicating work after it is gripped in the chuck to see that it rotates truly, and also to meet the need in those cases where it may be necessary to face a shoulder or collar at the same chucking as the thread is cut, so as to ensure perfect concentricity. Such turning operations may be done by the slide rest attachment. The direction of rotation of the spindle may also be reversed by means of a lever. This actuates a clutch in the gear box at the back of headstock which is keyed to the same shaft as the step cone, which in turn is driven from a corresponding cone on the countershaft, thus providing for four variations of spindle speed in addition to the two speeds in the headstock. The four-groove pulley on the end of the spindle is used for a direct drive from a supplementary reversing countershaft, by means of which the spindle may be rotated quickly for the purpose of returning the saddle without disengaging the lead nut at the completion of a cut.

The front of the spindle has a taper socket to receive chucks, &c. The illustration shows a split collet chuck in use closed or released by means of a threaded sleeve on the front of the spindle, which, for convenience, is rotated by the crank handle on the top and worm which is enclosed in a bracket. This bracket is pivoted so that the worm may be engaged or disengaged with the wheel on the revolving sleeve, being held in or out of gear by a plunger pin.

The lead screw for traversing the carriage is at the back of the machine. This is driven by change gears from the spindle through a short shaft and a claw clutch covered by a guard. The clutch is operated by a lever at the front of the machine, so that the traverse of the carriage may be engaged or disengaged at will, and the carriage may be traversed by hand by means of the hand wheel when desired. There are many provisions made for adjustments, changes of spindle speeds, and automatic devices, but the limited space at our disposal prevents us describing these at greater length. We may, however, just mention that the slide rest attachment, as shown in the illustration, consists of a removable bridge piece bolted to the bed so as to span the saddle. On this is mounted a slide rest with longitudinal adjustment by rack and pinion and cross adjustment by screw. The value of this attachment consists in the facility for turning faces or shoulders that must be true with the threaded part, accuracy being ensured by both operations being done at the same chucking.

The "Sunderland" gear planer shown by Messrs. Parkinson & Son, which made its début to the public at Olympia two years ago, has now established its reputation, and it is interesting to learn that the identical machine then shown was supplied to a firm that has since ordered 16 more of these machines in various sizes. The machine exhibited by Messrs. Parkinson & Son was of a size larger than the one shown in 1910, and was capable of cutting spur gears up to 40in. diam., 9in. face, and 2½ D.P. at a very rapid rate. A recent test on a similar machine resulted in a cast-iron wheel 40in. outside diameter and 4in. wide, having 100 teeth 1¼in. circular pitch, or 2½ D.P. being cut in two hours. Those who maintain that under modern conditions cut gears are more economical, even from the machine builder's standpoint, than cast-iron gears are, will appreciate that such possibilities for rapid gear planing as the "Sunderland" machine offers are a very valuable contribution to their side of the argument.

The "Sunderland" process of gear planing is based on the use of a cutter which is really a section of rack of involute form, the rack or cutter being mounted on a slide which reciprocates across the face of the blank. The cutter also receives, in the intervals between the cutting stroke, a definite movement at right angles, that is, at a tangent, to the pitch circle of the gear being cut, and simultaneously the blank receives a relatively equal rotary movement, so that a generated form of tooth is produced, and any gear cut by the same cutter will gear correctly with any other gear so cut. When the combined movement of gear and rack cutter has equalled

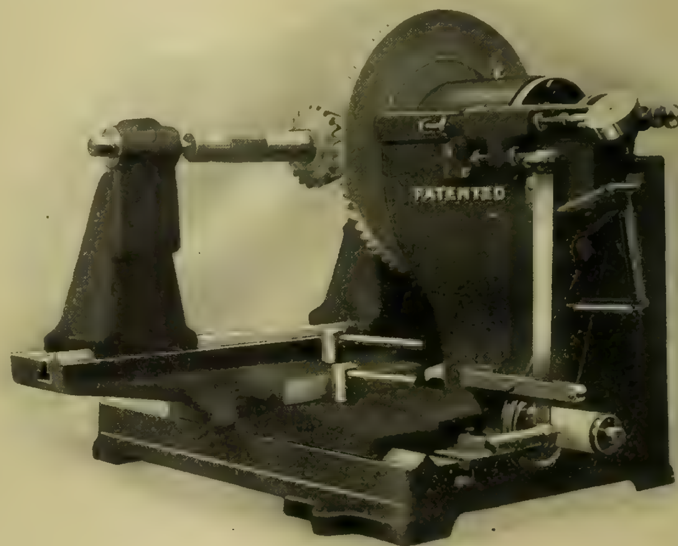


FIG. 4.—BEVEL GEAR TESTING JIG, WITH RECORDING DEVICE. MESSRS. PARKINSON & SON, SHIPLEY.

the width of one tooth and space, or one complete pitch, the movement ceases, the blank is withdrawn from the cutter and the cutter returned in the opposite direction to its starting point, whereupon the blank and cutter are re-engaged but one tooth later, and the process repeated. This all takes place automatically in less time than it has taken to describe. It will be understood that the cutter or rack is generating the form of the teeth during the whole arc of contact, including the approach and recess, and is cutting on all the teeth within that arc at the same time, but after the first few cycles of the movements described each one represents a tooth completed. It will also be obvious that only one cutter is necessary for each pitch, and that a very small outlay on cutters will cover a very wide range of requirements.

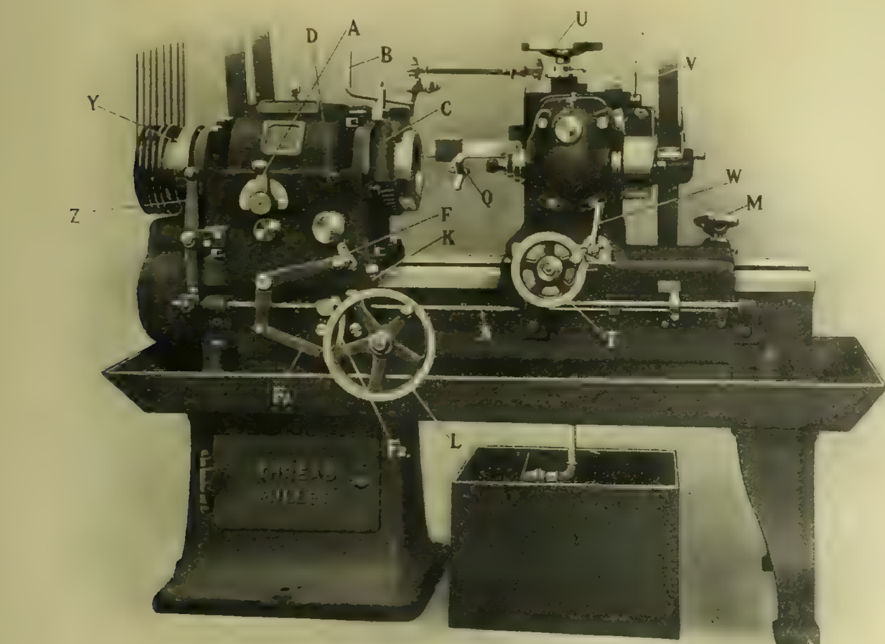


FIG. 5.—THREAD MILLING MACHINE. MESSRS. PARKINSON & SON, SHIPLEY.

The No. 5 machine on show at Olympia was driven by a 10 h.p. motor and was fitted with davit and chain blocks for handling heavy blanks. This machine is suitable only for cutting spur or sprocket wheels, but a modification styled the No. 5A machine will also cut spiral wheels by swivelling the cutter slide at an angle across the face of the blank, as illustrated in Fig. 6 By a slight modification of the cutter it is also possible to cut double-helical gears, and a further and more remarkable proof of its adaptability is its ability to produce spiral milling cutters, the teeth of which are "generated" by a suitably shaped "rack" fitted to the machine.

Messrs. Beckenback & Co., of Bradford, Yorkshire, exhibited what was perhaps the heaviest and most massive tool in the show. This was a horizontal hot forging machine of the latest type, B.S.S. IV. C., made by the firm of Maschinenfabrik Hasenclever A. G., of Dusseldorf, Germany. A variety of articles forged on the machine were also shown. These included railway buffers, sleeves, shackles, spring buckles, large bolts, &c. The most varied kinds of forging can, however, be produced on them, small bolt heads being produced at one blow, and larger pieces with several blows. A side shear cuts the finished product to length, and, when required, the machine can be arranged for bending purposes. The heated bar is inserted in clamping jaws as far as a stop, adjusted for the work in hand, allows. The jaws then securely grip the shank, while the stamp upsets the head, whereupon the jaws again open and the finished product is cut to length on the shear. The machine, which we regret we are unable to illustrate, is set in motion by pressing down a treadle; on releasing this the upset slide stops in its rear position, but the main shaft continues to run. The upset slide is actuated by a plunger rod from the crank, the upset die striking direct, while the clamping jaws are closed by an adjustable lever actuated by the upset or stamp slide. A double tool can be used for upsetting and finishing at one heat, and a breaker, fitted to the jointed lever, and another fitted to the plunger slide, prevent the limit of pressure being exceeded, either through carelessness on the part of the operator, or through using cold material. By means of these machines it is claimed that one man can do more work than three or four men forging in the old-fashioned way.

Other machines shown by the firm we specify below. A cold nut forging machine in operation, producing ⅜in. Whitworth hexagon chamfered nuts at the rate of 60 per minute, or about 25,000 per day. This machine was fitted with automatic feed for the coil of rolled bar, the tools themselves being stationary; this, the firm claim, ensures that the nuts have central holes as well as central chamfers. The nuts, as they left the machine, we noticed at the time of our visit to the stand, had no burr and were ready for tapping,, which operation was performed by a self-acting nut-tapping machine, also shown at work The nuts were placed in a tray, and caused to come automatically before a tap, which reversed on completing its work, the tapped nut being afterwards ejected. These machines, we were informed, have an output of about 3,500 to 5,000 nuts per day, and one boy can attend from 10 to 15 of them.

Another ingenious machine shown by the firm was an automatic assembler for screwing the tapped nuts on to bolts. This also was shown in operation. Two trays are fitted to the machine, in one of which the nuts are placed, and in the other the bolts. From these trays they are taken automatically by the machine and fed down chutes, and when they reach the bottom they are assembled and afterwards ejected.

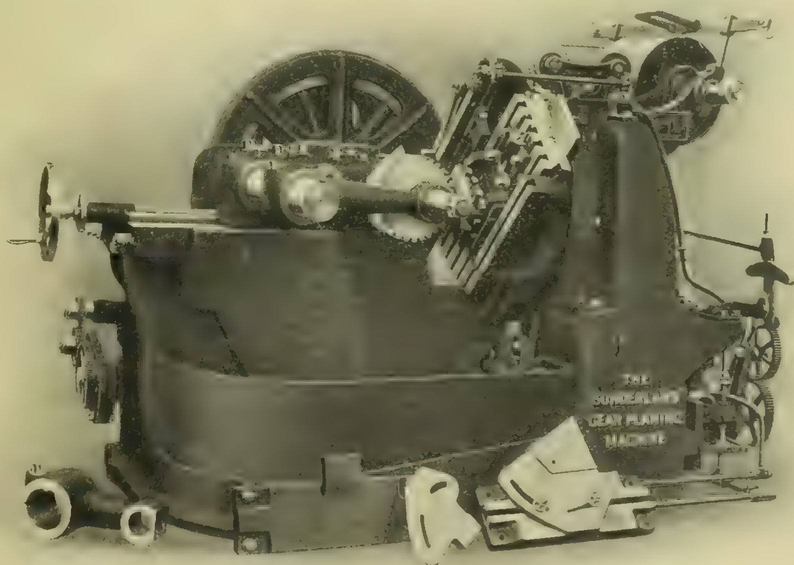


FIG. 6. "SUNDERLAND" GEAR PLANER CUTTING SPIRAL GEARS MESSRS. PARKINSON & SON, SHIPLEY

Patent wire nail machines, manufactured by Messrs.

Wikschtroem & Bayer, of Dusseldorf, were represented by two sizes, both of which were shown in operation producing wire nails *entirely without point scrap*. The large machine produced about 320 nails per minute, and the small machine about 700 per minute. This feature of working without scrap should do much to revolutionise the wire nail trade, as the saving in wire is very considerable. The nails produced can have either central or diamond-shaped points as desired.

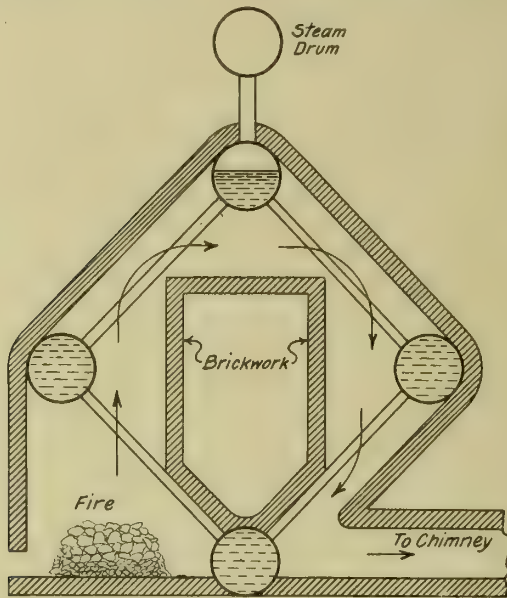


FIG. 7.—DIAGRAMMATIC VIEW OF THE "DIAMOND" WATER-TUBE BOILER. MESSRS. ARTHUR ROSS, HOTCHKISS, & CO., LTD., LONDON.

Fully automatic lathes for producing all kinds of screws and shaped articles, with and without threads, were represented by six machines of the "Wuttig" patent type. Three machines were shown in operation on brass, viz.: A No. 6, producing up to 42 screws per minute, complete with slotted heads, and delivered into separate box away from the swarf; a No. 13, producing cycle pump nipples with two threads and knurled, complete, at the rate of 4 per minute; and a No. 26 automatic, producing an article with two threads complete.

The following machines were shown in operation on mild steel: One No. 10 automatic, producing 2 BA round-head slotted screws; one No. 26 automatic, producing ⅜in. Whitworth hexagon screw bolt; and one No. 1 nut automatic, producing ⅜in. Whitworth hexagon nut, not tapped, at the rate of four per minute. This machine works with accelerating speed, as the cutting diameter diminishes, so that the parting-off tool always works at the same cutting speed. In these machines the spindle and die run uninterruptedly in the same direction, and the die does its work simultaneously with the turning, shaping, and parting-off tools. As no tool need work

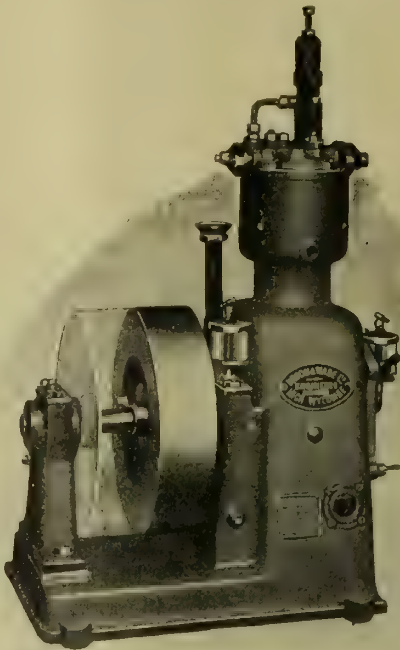


FIG. 8.—SINGLE CYLINDER AIR COMPRESSOR, SHOWING AIR GOVERNOR. MESSRS. BROOM & WADE, HIGH WYCOMBE.

separately, the result is therefore highest efficiency. There is no reversing, consequently all the usual more or less complicated gear is abolished, and the setting and adjustment of them becomes exceedingly simple, and changing from one article to another is quickly effected. Special drilling attachment is fitted, likewise operating simultaneously with the other tools. Long or short screws can be slotted, without reducing the output, and these are deposited into a separate

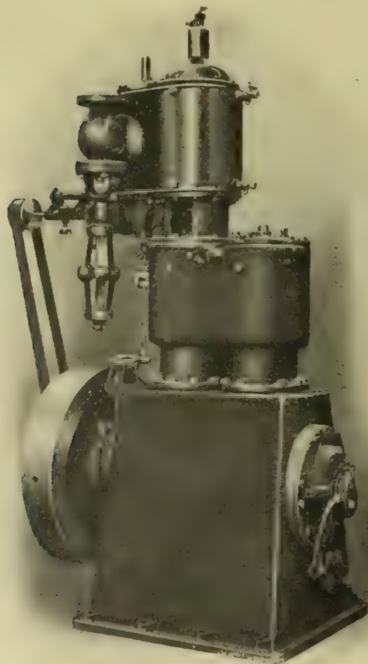


FIG. 9.—TWO-CYLINDER STEAM-DRIVEN AIR COMPRESSOR. MESSRS. BROOM & WADE, LTD., HIGH WYCOMBE.

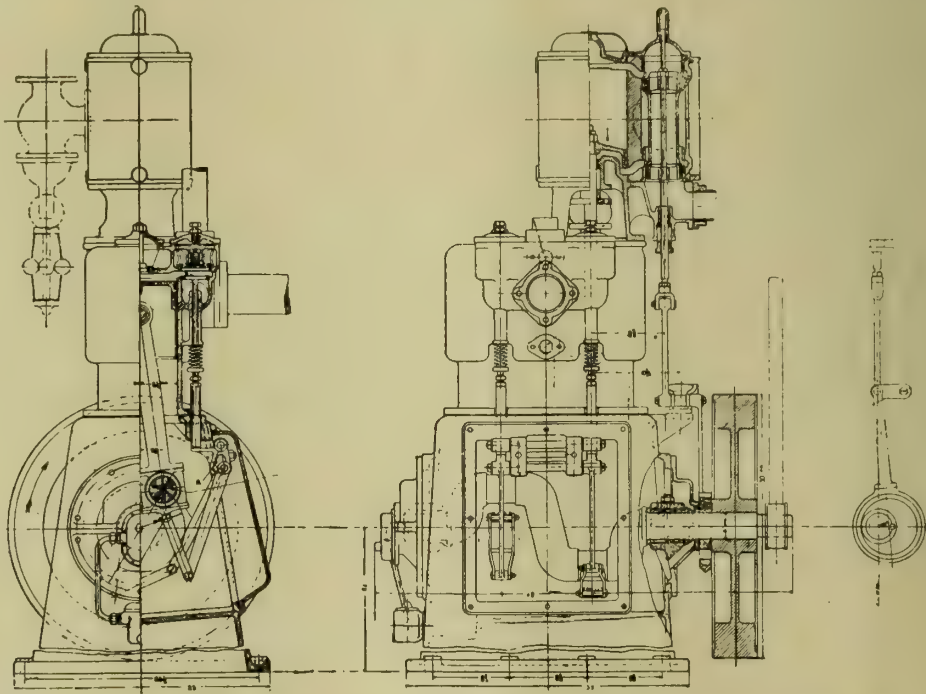


FIG. 10.—SECTION OF TWO CYLINDER STEAM-DRIVEN AIR COMPRESSOR. MESSRS. BROOM & WADE, LTD., HIGH WYCOMBE.

box away from the swarf and lubricant by an automatic "Thief." For articles with two threads an extra toolholder is fitted, enabling the second thread to be made and the article to be turned out complete without requiring extra time for cutting the threads.

Messrs. Hall & Pickles, of 64, Port Street, Manchester, supplied the bright, cold-rolled steel bars, and "Hydra" high-speed tool steels used in the above-described automatic

machines, and we were impressed with the uniform quality of the former, and the cutting and lasting properties of the latter. The "Hydra" tool steel we mention is made, we understand, exclusively for Messrs. Hall & Pickles by an old-established firm of tool steel melters in Sheffield, and is claimed to be second to none in the market. Three kinds are supplied by the firm, viz.: "Hydra" high-speed vanadium steel for water-hardening; "Hydra" high-speed steel for air-hardening; and "Hydra" turning tool steel for turning chilled rolls, iron and steel castings, &c.

Messrs. Arthur Ross, Hotchkiss, & Co., Ltd., of 1, Glengall Road, Old Kent Road, London, S.E., exhibited their well-known Hotchkiss circulator, an appliance for automatically circulating the hottest water to the bottom of boilers from the time the fires are lit till they are cold, and also continuously removing mud, oil, &c., from the boilers while they are at work.

A model of a "Diamond" water-tube boiler was also shown at work on this stand, being publicly exhibited for the first time at the exhibition, and we give herewith a diagrammatic illustration (see Fig. 7) showing the principle of heating involved. As will be seen, there are five drums, four of which form the circulating and steam-generating

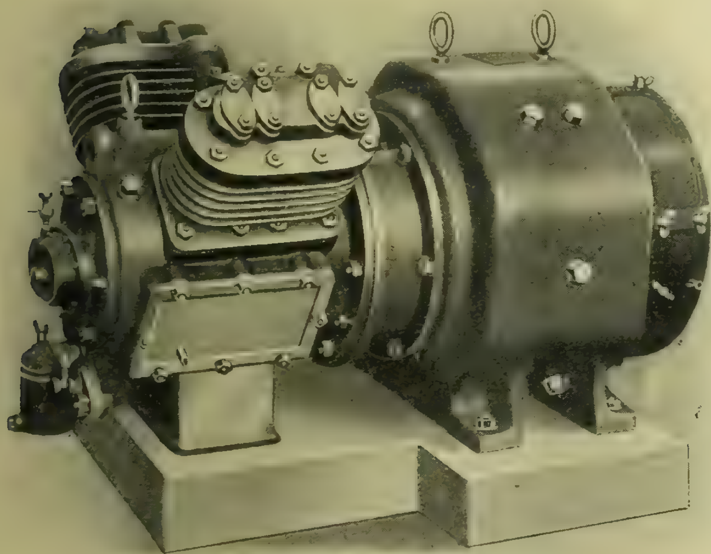


FIG. 11.—RAILWAY COMPRESSOR. MESSRS. BROOM & WADE, LTD., HIGH WYCOMBE.

system proper, while the fifth is used as a steam drum. The course of the hot gases is indicated by arrows.

The chief features claimed for the boiler are: That it is easy to clean and examine; each tube, which is short and straight, has full freedom to circulate the water; it has a large heating surface; and superheater and air heater can be accommodated, without needing more floor space.

The model boiler shown at the Exhibition worked perfectly, and as the ends of the drums were fitted with glass plates, it was possible to note the circulation of the water and generation of steam with ease.

Another device also publicly shown for the first time at this stand was a new condenser ferrule which it is claimed entirely does away with the use of grummet or other packing. They make a perfectly tight joint, and it is claimed for them also that they will not cause corrosion of the tube ends.

Messrs. Broom & Wade, Ltd., of High Wycombe, exhibited several types of their well-known air compressors, together with standard types of the Hyatt roller bearings, of which they are the sole makers and concessionaires. Several of the compressors we have pleasure in illustrating in the accompanying cuts, and these, together with the description below, will enable their general design and operation to be understood.

Fig. 8 shows the single-cylinder air compressor, this being suitable for driving by belt. Owing also to its being self-contained, totally enclosed, and therefore entirely protected from dust, it is particularly adapted for use with a portable plant. The cylinders are water jacketed and valves are of ample size with small lift, the latter being made so that in case of breakage they do not fall into the cylinder. They are constructed of the finest nickel steel, and are thus

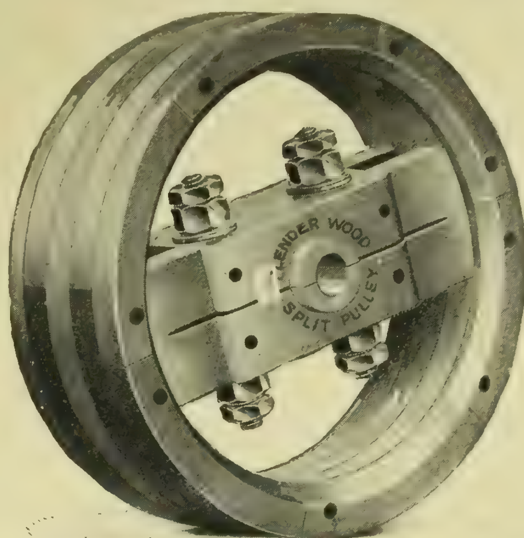


FIG. 12.—FLENDER WOOD SPLIT PULLEY. MESSRS. THE FLENDER COMPANY, LONDON.

practically indestructible, while the piston and cylinder are made of close-grained iron. An air governor is fitted as shown, which is very compact; and doors fitted to the case give easy access to all working parts. As regards lubrication, the two bearings of the crank shaft are fitted with ring oil bearings, while the connecting rod is provided with drip feed and banjo lubricator, and is also lubricated on the splash system. Should the drip feed fail from any cause, the compressor could, it is stated, run for several days without damage.

Figs. 9 and 10 show Messrs. Broom & Wade's two-cylinder steam-driven compressor. This type is arranged with steam cylinder, or cylinders, according to the power required,

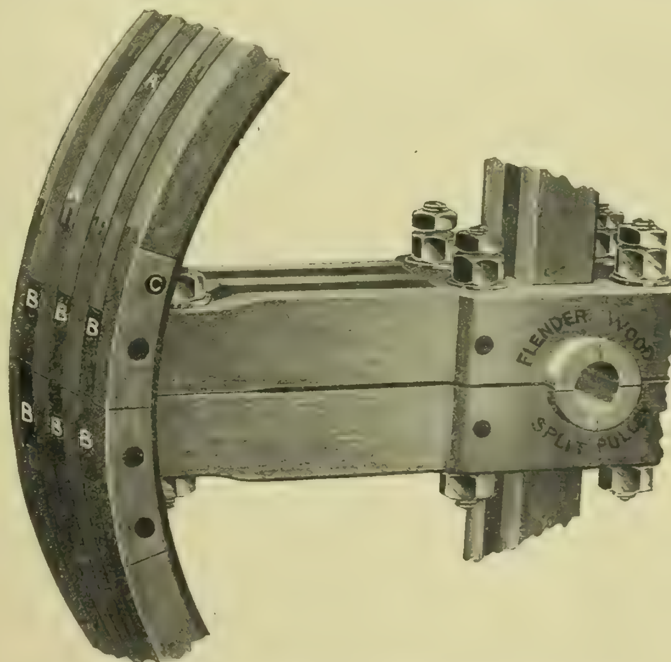


FIG. 13.—FLENDER WOOD SPLIT PULLEY. MESSRS. THE FLENDER COMPANY, LONDON.

carried on distance pieces placed on the top of the air cylinders.

The general construction will perhaps be better understood by a reference to the sectional view. As will be seen, the steam cylinder is fitted with valve of the piston type, while an efficient throttle governor driven by belt from the crank shaft and having a wide range of adjustment is provided. The air valves are contained in a pocket on the side

of cylinder, thus leaving the whole of the cylinder head available for efficient cooling, while the suction valves, being mechanically operated, open and close without shock.

The speed of the compressor is regulated to a point at which the inertia of the line of moving parts, with a minimum of assistance from the flywheel, will overcome the severe compression which occurs at the end of a stroke. At the same time the speed is kept down so that maximum cooling effects are obtained from the compressor water jacket.

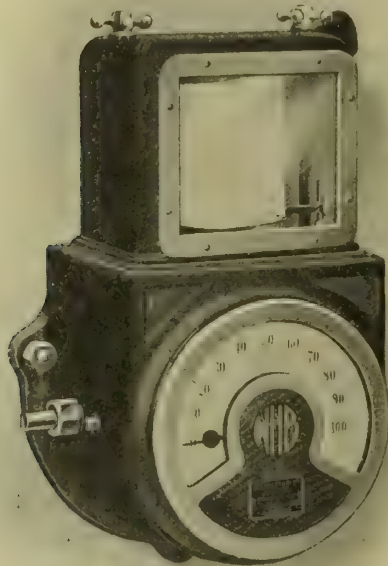


FIG. 14.—TELL-TALE RECORDING GAUGE. MESSRS. W. H. BAILEY & CO., LTD., SALFORD.

Smooth running is thus ensured, and wear and tear on the working parts is reduced to a minimum.

Forced lubrication is used, a rotary gear oil pump being mounted direct on the end of the crank shaft which is positive in its action and has only one pipe connection, viz., to the oil well in the compressor base. It delivers oil through its own case by means of a hole drilled through the crank shaft to each bearing, and the crank pin.

A railway type compressor is shown in Fig. 11, these having four cylinders cast in two pairs, as shown. The cylinders are 3in. by $3\frac{3}{4}$in. stroke, and the machine delivers 35 cub. ft. of free air per minute at a speed of 570 revs. per minute.

The crank is a two-throw one, carefully balanced, and efficiently lubricated by forced lubrication. The cylinders are staggered on the crank base, and each crank bearing carries two connecting rods. This arrangement is equivalent to a four-cylinder machine with cranks set at equal angles, and a perfectly uniform turning movement is thus obtained, whilst it forms a more compact arrangement than with four cylinders placed equally round the crank shaft. The suction valves, which are of mushroom type, are made of nickel steel, and are closed by means of a spring. The pistons are ground and fitted with hardened and ground gudgeon pins, three Ramsbottom piston rings being also fitted, which are ground on the periphery and two edges.

A volumetric efficiency of 87 per cent. is obtained, and, owing to the absence of gear and lightness of working parts, practically silent running is the result, with very high overall efficiency.

A four-cylinder 10in. by 12in. belt-driven compressor was also shown, but we regret that we cannot devote space to illustrate it. It follows closely the general design of the other machines, with the exception that the discharge valves were of a steel-plate disc type of the firm's own design. These open and close automatically, and have no springs except that due to the springing in of the plate disc itself. They work perfectly noiselessly, and can be removed and replaced in a moment. Efficient lubrication is provided throughout by means of a geared oil pump fixed direct to the crank shaft and mounted on to the outside of one of the end covers. This opens for inspection and cleaning at any time, even when the compressor is running. The main bearing at the flywheel end gets its oil direct from the oil pump by a separate pipe so as to ensure it being lubricated from the first start. The oil pump is provided with a by-pass which has a spring regulating overflow valve whereby the oil pressure can be regulated to suit the most exact requirements. By this system of lubrication a most satisfactory way of distributing the oil is obtained, and the only attention required is to prevent the oil in the pump dropping below a certain line on the indicating glass.

Messrs. The Flender Company, of Broad Street House, New Broad Street, London, E.C., had an interesting display of their well-known speciality, the Flender wood split pulleys, including very large sizes up to 12ft. diam. Up to 37in. diam. these pulleys are made with two arms, as in Fig. 12, but over that size they are fitted with four, as shown in Fig. 13. The rims are built up in distinct rings, as clearly shown in the illustrations we give, and these rings are, in turn, made of a number of segments, which are dovetailed at each end. The arms of the Flender pulley pass right through the rim, flush with the driving surface, and are dowelled and glued in position, while the "split" segments—*i.e.*, the halves—of the pulley interlock together, so that no lateral movement is possible. No metal is used in the rim whatever, and so no unequal expansion and contraction results; and when mounted on the shaft the pulleys are as firm and solid as any metal ones, whilst not being anywhere near so heavy. As regards weight, the firm inform us that "Flenders" are 70 per cent. and 40 per cent. lighter than iron and steel pulleys respectively, and thus it is that they require less power to rotate them. Also the lighter the shafting, and the lower the bearing friction, this resulting in two clear gains of power. A great advantage possessed by these pulleys is that they have no keyway, and no dismounting of the shaft is necessary to fit them, the two halves being bolted together over the shafting, and firmly fixed by any workman in a few minutes. Also by means of standardised interchangeable bushings they can be readily transferred from one shaft to another of different diameter with ease.

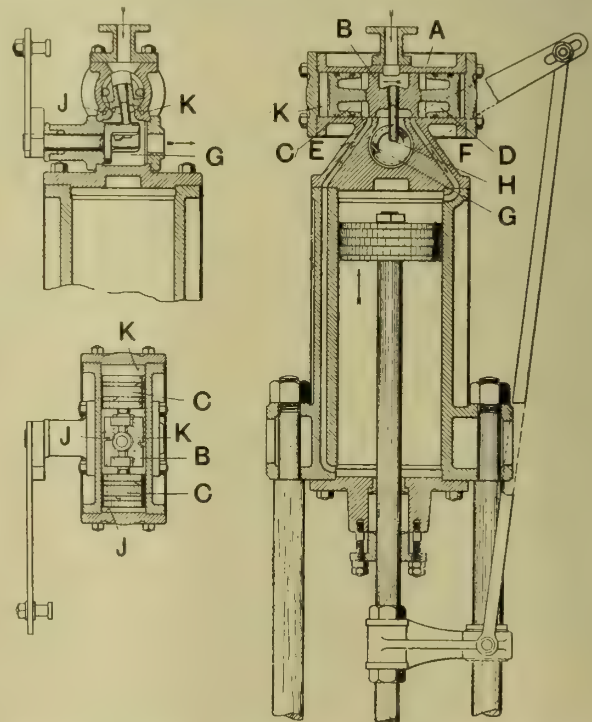


FIG. 15.—"DAVIDSON" PATENT STEAM PUMP, VERTICAL PATTERN. MESSRS. W. H. BAILEY & CO., LTD., SALFORD.

Messrs. W. H. Bailey & Co., Ltd., of Albion Works, Salford, Manchester, exhibited a very full and representative selection of their manufactures in the shape of boiler feed

pumps, air compressors, recording oil testers, lubricators, instruments for recording and indicating steam, air, and water pressure, cement testers, and reducing valves. The exhibit was so varied that we can only, with the space at our disposal, refer to one or two of the firm's specialities.

Fig. 14 shows a recording "Tell-Tale" gauge for pressure and vacuum exhibited by them. This, as will be seen, is a neat and convenient instrument for indicating and recording steam, air, gas, and water pressure at any distance from the source of pressure. It is a cheaper form of the firm's pressure recorder, being without clock dial and having a smaller case. It is fitted, as will be noticed, with a straight-line diagram, and this gives an evenly-spaced record intelligible to anyone, and not so confusing as a disc diagram. The recording drums and clocks are self-contained units, easily detachable from the case and interchangeable one with another, and are contained in a separate compartment, which is rendered dirt, wet, and gas proof by means of a rubber packing ring. The eight-day clock movement which is contained within the drum, and therefore well protected from injury, is fitted with regulator and lever escapement.

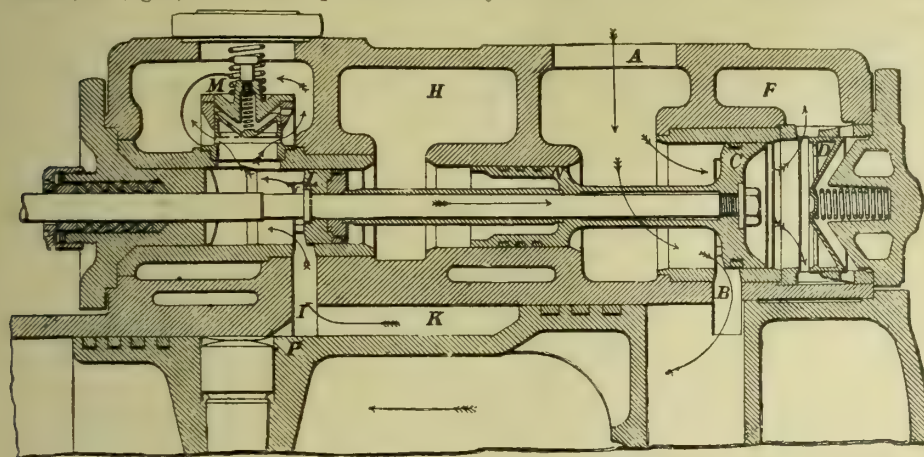


FIG. 16.—"KOSTER" 2-STAGE AIR COMPRESSOR, SHOWING OPERATION OF PISTON AND VALVE GEAR. MESSRS. W. H. BAILEY & CO., LTD., SALFORD.

Fig. 15 shows sectional views of a vertical type of "Davidson" steam pump exhibited by Messrs. W. H. Bailey and Co., Ltd., and the following short description will enable its action and working to be understood.

As will be seen, it is of the single-cylinder type, which is not only simple in construction, but economical in the use of steam. It will, we are informed, start from any point of the stroke; make its full stroke under all conditions; and will pump any fluid, giving a steady and uniform delivery, against light or heavy pressures, and at low or high speeds.

The steam valve gear consists of a slide valve, valve pistons, valve pin, and cam. The slide valve is actuated by a positive mechanical connection with the main piston rod and by the action of steam on the valve pistons. The illustrations show the valve gear applied to a vertical steam cylinder. The steam chest consists of the cylinder A, and contains the slide valve B and valve pistons C and D. The pistons are connected, sufficient space being allowed between them for the valve B and steam ports E and F. The valve is controlled and operated by the steel cam G acting on steel pin H, which passes through the valve into the exhaust port in which the cam is located. In addition to this mechanical operation, steam is alternately admitted to and exhausted from the ends of steam chest by ports J and K, operating the pistons C and D.

The pump being at rest, with the valve B covering the main steam ports E and F, the cam G holds the valve by means of valve pin H, so that ports J and K admit steam to one end of chest and connect the other end with exhaust port; the steam acting on valve pistons will now move valve pistons and valve, opening main ports E and F, admitting steam to one end of the steam cylinder and opening the other end to the exhaust. If the valve occupies any other position, the main ports E and F will be open for the admission and exhaust of steam; consequently it is evident that there is no dead point, and that the pump will start from any point of the stroke.

Steam being admitted to the cylinder by one of the main ports, as E in illustration, the steam piston, cam, valve, &c., will move in direction indicated by arrows. The first movement of the cam will be to oscillate the valve, preparatory to bringing it into proper position for the opening of the auxiliary steam port J to live steam and K to exhaust, and secondly, to bring the valve to its closure (mechanically) slightly before the end of the stroke of main piston (thereby causing slight cut-off and compression) and fully opening auxiliary port J to steam and K to exhaust. By the admission of steam to one end of chest, the other being open to exhaust, the valve pistons will move valve to such position as will allow the admission and exhaust of steam to and from the cylinder for the return stroke. The main valve also being as much under the control of the piston rod as is the valve of an ordinary steam engine worked by an eccentric, secures a positive action, the pump thus being capable of starting from any position and maintaining a uniform and full stroke. The steam piston is also absolutely prevented from striking the cylinder heads by virtue of the mechanical valve closure, so that the clearance at the end of cylinder can be less than in other designs. This, it is claimed, is one of the most important features of the pump.

The "Koster" air compressor, another speciality exhibited by the firm, we have pleasure in partially illustrating in Fig. 16, this being a section view showing the operation of the piston and valve gear. In the suction and clearance discharge stroke of this compressor it is claimed that a thick stream of air is admitted by the use of the piston inlet valve and that this is not wire drawn and therefore does not get so hot as when it passes through ordinary valves in a thin stream. The piston inlet valve also performs other duties: (1) It discharges the compressed air remaining in the clearance spaces of the valve chest through the discharge valve; and (2) it prevents any leakage from the discharge valve passing into the cylinder, and therefore assists to form a double check on the compressed air in the discharge pipe. At the end of the suction stroke the cylinder is filled with air at atmospheric pressure and at a low temperature, so that the volumetric efficiency is remarkably high.

On the compression and major discharge stroke air is compressed in the cylinder to a pressure equal to and no higher than the pressure in the discharge pipe, and passes through a single valve of the large size and high lift which is air cushioned in opening. On the completion of the discharge stroke, the air passage from the cylinder is closed mechanically, so that the discharge valve is permitted to seat itself slowly and quietly. The reference letters shown on the illustration indicate the following parts: A, the suction inlet; B, port of low-pressure end; C, low-pressure piston valve; D, low-pressure delivery valve; F, to inter-cooler; H, suction of high-pressure end; I, port of high-pressure end; K, high-pressure end; L, high-pressure piston valve; M, high-pressure delivery valve.

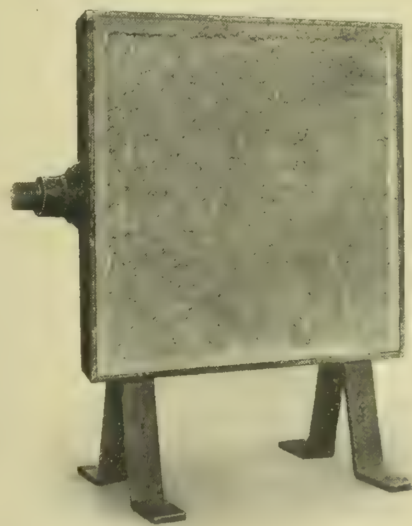


FIG. 17.—DIAPHRAGM HEATER. MESSRS. BONECOURT SURFACE COMBUSTION, LTD., LONDON.

Messrs. Bonecourt Surface Combustion, Ltd., of Parliament Mansions, Victoria Street, Westminster, London, exhibited several examples of furnaces and stoves fired with gas on the Bonecourt patent system (to be described below), as well as diaphragm radiators for domestic heating and cooking, &c.

In the yard outside the Olympia building was exhibited a gas fired boiler, also on the Bonecourt patent surface combustion system. It supplied steam to several of the exhibitors, and was shown at the Exhibition for the first time in any country. Gas and air were supplied under pressure by Sturtevant fans, and the water level was controlled by means of a Crosby automatic feed regulator.



FIG. 18.—METAL MELTING FURNACE, IMMERSED BURNER TYPE. MESSRS. BONECOURT SURFACE COMBUSTION, LTD., LONDON.

In the ordinary case of flame combustion the molecules of gas travel through a succession of envelopes in which various degrees of aeration prevail. The combustion is essentially a step by step process, and, as such, is broadly distinguished from the process of surface combustion. The distinguishing and essential feature of the new processes is that a homogeneous explosive mixture of gas and air, in the proper proportions for complete combustion (or with air in slight excess thereof) is caused to burn without flame in contact with a granular incandescent solid, whereby a large proportion of the potential energy of the gas is immediately converted into radiant heat. The advantages claimed for the new system are: (1) the combustion is greatly accelerated by the incandescent surface, and if so desired, may be concentrated just where the heat is required; (2) the combustion is perfect with a minimum excess of air; (3) the attainment of very high temperatures is possible without the aid of elaborate "regenerative" devices; and (4) owing to the large amount of radiant energy developed, transmission of heat from the seat of combustion to the object to be heated is very rapid.

There are two principal forms of the surface combustion element, one known as the "Diaphragm" (or No. 1 process), and the other as the "cavity cobble," or "Granular Bed" (No. 2 process). The former consists of a slab of porous fireclay of any required size and shape, mounted in a frame attached to a box or fuel chamber, from which the combustible or explosive mixture of gas and air, under a suitable pressure, percolates through the porous diaphragm till it reaches the outer face, where it can be ignited. If less air than is theoretically required be present in the mixture, flames will appear on the face of the diaphragm and it will become heated. On reducing the richness of the mixture, but still maintaining the pressure, these flames will disappear, and in a very short time the mixture will begin to burn inside the porous slab at about ⅛in. from its surface, producing an incandescent or glowing surface devoid of flame and giving out great radiant heat. The temperature near the surface is about 850° C. = 1,562° Fah.

The coarseness or fineness of the porous diaphragm is graded to suit the quality and pressure of the gas employed, so as to secure the required results. Generally speaking, with a rich gas, such as coal gas, or water gas, a finer grade is used, while for "poor gases" and moderate temperatures a coarser grade is employed. Obviously, the finer the grade the higher must be the pressure, varying from ⅛in. of water to over 4in. Any kind of gas can be used, from rich coal gas to producer gas. In cases where a supply of gas is available under a pressure of about 2lbs. per square inch the gas may be made, by an injector nozzle, to induce all the air for combustion through a simple adjustable orifice, so as to obtain and maintain the proper mixture. Where a supply of high-pressure gas is not available a fan or blower may be used to create pressure in the gas, or to produce a current of air under pressure to induce low-pressure gas, and form the required mixture. Or, again, a single blower may be used to form and deliver a mixture of air and gas, without any risk of back-firing or explosions. The pressure of this mixture in the supply chamber at the back of the diaphragm only requires to be that due to ⅛in. to ¼in. of water when the face of the diaphragm burns under atmospheric pressure. With the granular bed form, and particularly when used in a long tube packed with granules, this pressure must be higher to overcome the resistance of the much greater length or depth of porous material. The principal uses of the diaphragm form are: (1) evaporation of liquids by radiant heat thrown on to the surface of the liquid; (2) concentration of sulphuric acid; (3) industrial heating; and (4) domestic heating, cooking, toasting, washing, drying, &c., particularly in hotels and large public institutions.

The second form of the apparatus (No. 2 process) presents even a wider field of application than the diaphragm (or No. 1 process) which arises partly from the fact that higher temperatures can be obtained (over 2,000° C. = 3,632° Fah.) and that the arrangement permits of the application of the process to all shapes and sizes of furnaces. The principles involved are the same in both, but the physical arrangement of the active elements is substantially different. In the No. 2 process the diaphragm is replaced by a bed of granular refractory material on the surface of each granule of which flameless incandescent surface combustion occurs. These granules can be easily packed into tubes which can be bodily immersed in water for steam raising purposes, or in metals and alloys which it is required to melt. They can be packed round a crucible, or be arranged in the form of a bed in a furnace for heating bars of iron or steel which require stamping or forging, while large masses of metal such as guns, armour plate and the like can be subjected to a heat-soaking process to facilitate annealing, tempering, or other processes in the working of steel and other metals. The above brief description is only intended to give a general idea of the principles and chief uses of the system and is in no sense complete or exhaustive.

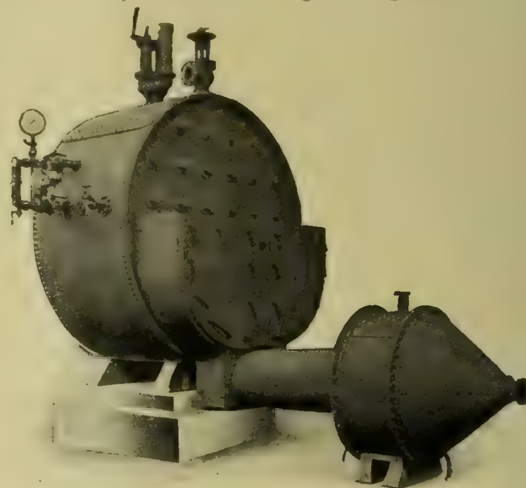


FIG. 19.—THE BONECOURT PATENT BOILER. MESSRS. BONECOURT SURFACE COMBUSTION, LTD., LONDON.

In Figs. 17 to 19 we give three illustrations of the apparatus in various forms, Fig. 17 being a diaphragm heater, Fig. 18 a metal melting furnace for melting lead, antimony, type metal, &c., in which it is claimed that one ton of lead can be melted at a cost of 4½d. with town's gas at 2s. per thousand, and Fig. 19 a photograph of a boiler similar to the one shown at the Exhibition and fired with coke-oven gas, at the Skinningrove Ironworks, capable of evaporating 5,500lbs. of water per hour, into steam at 120lbs. pressure, with an efficiency of 94 per cent.

Railway Flashlight Signals.—As a result of a year's trial installation of the Aga system of flashlight signals on the Liljeholmen station of the Swedish State Railways, the State Railway Authorities have decided to adopt flashlight for two new types of signals, which have been designed by Mr. E. G. Windahl, signal engineer of the Swedish State Railways. To this end the whole line between Stockholm Central Station and Saltskog will very shortly be equipped with these new flashlight railway signals.

FIRE EXTINCTION ON SHIPS.

AN exhaustive paper on "The Use of Gases on Ships for Fire Extinction and Fumigation" was read by Mr. E. Kilburn Scott, A.M.Inst.C.E., at a meeting of the Institute of Marine Engineers on November 18th. The author stated that fire was one of the principal risks of sea transport, because it was an ever-present one. As the interior fittings of passenger vessels became more and more elaborate, so did the fire risk increase, but, of course, the greatest danger lay in the holds, and it was with the latter that his paper was principally concerned. The possible damage due to a fire increased as steamships increased in size. The larger the holds the more non-conducting material there was between the seat of the fire, for it generally broke out in the centre and the cool surfaces of the skin of the vessel or the deck above. The problem of fire extinction on shipboard was in some respects similar to that which fire brigades ashore had to deal with. An ocean liner might be considered as analogous to a theatre or hotel, where human life was principally involved; while a cargo-boat was similar to the warehouse or store where economic interests were at stake. The resemblance ended there, because a ship's fire differed from a fire in a building in that it could only be attacked from above. Also, as it was in an enclosed space and partly below water level, water had to be very carefully used. A principal difference lay in the fact that it was possible to make use of inert gases for fire extinction. The methods of extinguishing fires on board ship were: (1) Closing the hatches. (2) Flooding the holds with water. (3) Blowing in steam. (4) Blowing in an inert gas. The inert gases generally used were (*a*) carbon dioxide gas, (*b*) sulphur dioxide gas, (*c*) flue gas.

Closing the hatches was, he said, seldom really effective, because air usually leaked into the hold in sufficient quantity to keep the fire alight, and even when the flames were extinguished there was great danger of the fire breaking out again when the hatches were opened. The problem was not merely to arrest combustion, but to reduce the general temperature to a point at which air could be safely readmitted.

By reason of the latent heat of steam a large amount of heat could be quickly absorbed by evaporating water, but, of course, much water might be poured in without any of it reaching the seat of the fire. When the water did reach the fire the volume of steam given off acted in two ways—(*a*) by absorbing heat in its vaporisation, (*b*) by filling the hold and so displacing air. The principal objections to water were that it might seriously damage the cargo and also endanger the stability of the vessel. Many cargoes retarded the percolation of the water—for example, coal and grain, also fibres, such as cotton, wool, and jute. There was a further danger with such cargoes, that when wetted they swelled, and might twist the framing of the ship. Of course, water was the only medium possible for deck cargoes and for magazines containing explosives. British war vessels relied solely on water, but gas apparatus had been fitted on some foreign warships.

Steam, he observed, had the advantage that it could be quickly turned into a hold, but its value as an extinguisher depended principally on its displacing the air, and this depended on the amount of condensation. With some cargoes and in cold weather the penetration might be very small, owing to condensation, unless, of course, the cargo was well alight. If steam was used for putting out a fire, then there was so much less for the propulsion of the vessel. One grave danger in driving steam through a cargo that was well alight was that the steam might be dissociated into the explosive gases, carbon monoxide and hydrogen. That it was a real danger had been shown by Prof. Vivian B. Lewes. At the same time it was interesting to note that a steam system—the "Rich"—was in use on about 30 vessels, including some of the largest afloat. One reason why the Rich system was used was that it was designed for fire-indicating as well as fire-extinguishing.

Gas was, in his opinion, the best medium for fire extinguishing, because a captain naturally hesitated to inject steam or pump water into a hold full of valuable merchandise. The gas must be a non-supporter of combustion; must not condense and must not injure the cargo. Naturally, carbon dioxide was the first one to suggest itself, and it was of interest to note that so long ago as 1875 Mr. J. Glover proposed its use. His method of preparing the gas was not feasible, because he required about 4 tons of hydrochloric acid and chalk for every 1,000 tons of cargo. Although the earlier attempts to use gas were not successful, the very obvious advantages kept the matter uppermost in inventors' minds, and to-day there were three different systems at work: (1) The Gronwald system, using pure carbon dioxide which was stored in steel cylinders. (2) The Clayton system, using sulphur dioxide, which was made from raw sulphur in a special apparatus. (3) The Harker system, using the waste flue gases from boiler furnaces.

In the Gronwald system the fire-extinctive gas was stored in steel cylinders under pressure, so no machinery was required to deliver it; steam or water was necessary to provide heat for the gas. A feature of the system was that the gas acted not only as an extinguisher by diluting the air, but it also acted as a cooling agent, because of the low temperature produced. The bottles were the usual seamless steel type tested to 4,000lbs. per square inch, and at ordinary temperature the working pressure was about 765lbs. per square inch. One method of preventing clogging of the discharge was to provide a water jacket between the bottle and the reducing valve. This would do for a slow discharge, but for the very quick discharge necessary for fire extinguishing the water chambers would have to be large and the water have to be heated. There was danger in this, because if the discharge of carbon dioxide was stopped from any cause, heating of the liquid gas in the cylinder would take place and lead to an explosion. In the Gronwald apparatus the gas was not heated in its liquid state, but only after its issue in the vaporised condition. The heating medium was thus brought in contact with the gas in a fine state of subdivision, and consequently acted thereon without danger of the heat being carried back to the storage vessel. The heating medium might be steam or else water of ordinary temperature. The former was employed on steamers, whilst water was used on sailing ships, it being pumped through the ordinary deck pumps. Water might be used as the heating medium, because it surrounded the finely-divided gases at the moment of vaporisation. By means of the Gronwald valve and steam, a 40lb. bottle could be emptied in 5 minutes, whereas with an ordinary reducing valve it would take half an hour. Each pound of liquid gas expanded to about 8 cub. ft. of gas at atmospheric pressure. A cylinder weighing about 1½ cwts. contained 40lbs. of liquid or compressed carbon dioxide, and 50 cylinders would therefore provide about 16,000 cub. ft. of gas. Of course, it was not necessary to entirely fill the holds with pure carbon dioxide gas for fire-extinctive purposes; air containing 25 per cent. of carbon dioxide had an oxygen content of 15·7 per cent., and ordinary substances would no longer burn in it. Reckoning in this way, a hold of 60,000 cub. ft. capacity would be rendered fire extinctive in two hours by using the contents of 50 cylinders of gas, supposing two cylinders to be connected to the steam supply and delivery pipes at any one time. Of course, dilution could only be effective if the gas and air were thoroughly mixed. As the carbon dioxide gas was much heavier than air, most of it went to the bottom and diffused with the contained air. The safest plan was to put in such a volume of gas that the whole or nearly the whole of the contained air was expelled through vents left open for the purpose. The Gronwald carbon dioxide apparatus had been fitted to 70 vessels.

In the Clayton system sulphur was burned in a generator, and the products of combustion were cooled and then forced through pipes into the ship's holds. According to a Local Government Board report, the composition of the gas averaged about 10·5 per cent. of sulphur dioxide, 80·5 per cent. of nitrogen, and about 9·0 per cent. of oxygen. According to these figures, a ton of sulphur would produce about 180,000 cub. ft. of gas. The machine generally used for steamships measured 5ft. 8in. by 4ft. 10in., was 4ft. 8in. high, and weighed 33 cwts. The generator was charged with ordinary roll sulphur, and when gas was required a handful of cotton waste saturated with methylated spirit was placed on the sulphur and ignited. The generator door was closed after first starting the engine which drove the blower. Air

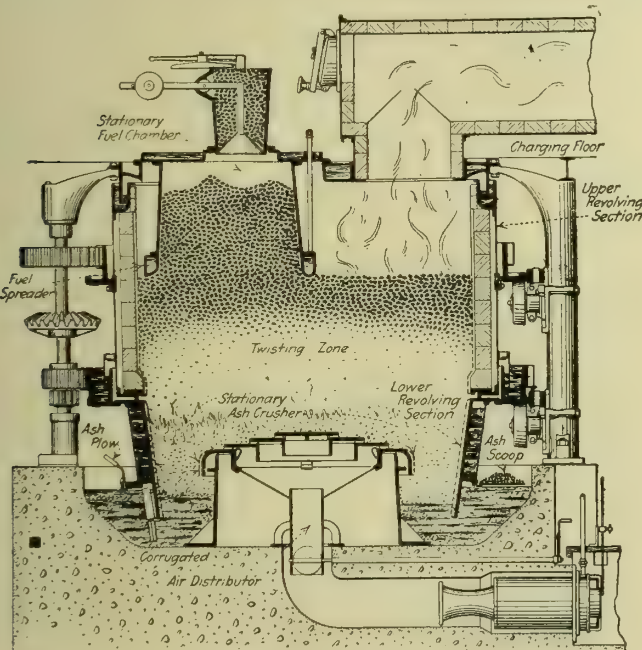
was drawn into the generator through the suction pipe which connected with the upper part of the hold or compartment to be treated. The air thus extracted passed into the generator, where the oxygen, combining with the burning sulphur, formed a fire-extinguishing and germicidal gas, which passed out through the cooler to the blower. It was then forced through the delivery pipe leading into the lower part of the hold or compartment to be treated. The fire was thus deprived of the oxygen necessary for its support, and such oxygen was replaced by sulphur dioxide gas. Of course, before it could be passed into the holds the sulphur dioxide gas had to be cooled to a little above normal air temperature. It might be thought that by so cooling some of the sulphur would be deposited as flour of sulphur, but such was not the case so long as the percentage of sulphur dioxide in the mixture did not exceed about 20 per cent. The latest machines were fitted with an automatic control to keep the gas below that percentage. The system differed from others in having both delivery and suction pipes leading from the apparatus and the hold. A powerful blower delivered sulphur dioxide gas to the bottom of the hold and drew air from the top of it, the volume withdrawn being about equal to that delivered. This was done not only to secure penetration of gas, but to economise sulphur. One objection urged against sulphur dioxide was that it attacked the metal work and spoiled some kinds of cargo. Over 200 steamships and 20 sailing vessels had been fitted with the sulphur dioxide system. Sulphur dioxide had been introduced into holds to prevent spontaneous combustion of coal cargoes, but as the gas was readily absorbed by moisture, forming an acid, it would not be suitable for any but a very dry coal.

Turning to the flue-gas system, the author said an ordinary fire received its supply of oxygen from the air, of which this gas formed 21 per cent. When the oxygen content was reduced to about 15 per cent. the combustion of ordinary substances ceased. When coal was burnt in a normal boiler a large part of the oxygen of the air combined with the coal, and the resulting flue gas only contained about 9 per cent. of oxygen. Thus flue gas was quite unable to support combustion, and it was the gas which was used in the system due to Mr. G. Harker, D.Sc. Being waste gas it cost nothing, but before turning it into the hold it had to be cleaned and cooled. A typical analysis of flue gas was: Nitrogen 80·5 per cent., carbon dioxide 10·0 per cent., carbonic oxide ·5 per cent., oxygen 9·0 per cent. In the Harker apparatus a De Laval turbine or electric motor drove the fan, and a branch pipe connected to the main funnel from the boilers or to the funnel of the donkey boiler conducted the gas to the washer and cooler. After being washed the gas then passed to the fan, and by it was delivered to the gas main. Sea-water was pumped into the washer, and was formed into a fine spray, which took out the soot as the gas passed on its way to the fan. Disinfectants could be drawn from a tank in a vaporised condition and carried along with the gas to all parts of the ship. In addition to a connection with the base of the funnel the machine must be connected with the uptake of the donkey boiler, so that gas could be drawn from it when the vessel was in port, or at any time the main boilers were not in use. A donkey boiler of ordinary size was quite capable of supplying a sufficient quantity of gas. The washing was effected in the following way. The gases passed downwards through a nest of six-sided cast-iron pipes; water also passed down at the same time, but at a quicker rate, so that an ejector effect was set up which reduced the suction head of the fan. The velocity of the gas was about 50ft. a second, and of the water about 120ft. a second. As the water shot through the gas it picked up the soot particles, and they ran off with the water at the bottom. The gas then returned to the top of the washer by a circular path, the whirl of which threw out more water, and it then passed to the fan clean. About 3,000 galls. of water per hour were required to cool down 90,000 cub. ft. of gas per hour to a temperature of 120° Fah. Under good working conditions, 1lb. of coal required about 18lbs. of air, a quantity which at ordinary temperature and pressure occupied about 196 cub. ft. During combustion most of the oxygen combined with the carbon of the coal, and was converted into carbon dioxide gas, which, when cooled, occupied exactly the same volume as the original oxygen consumed. Hence about 450,000 cub. ft. of flue gas were produced by burning one ton of coal. The fan delivered into a 6in. diam. galvanised steel riveted pipe, which ran fore and aft. Branch pipes, controlled by sluice valves, led down to the bottom of the holds and bunkers, and at the lower end of each of these branch pipes there was a specially constructed rose having 1in. holes, which prevented the cargo getting into the pipe, but allowed free escape of gas. Branches were led on deck to a hose coupling for disinfecting and fumigating the passengers' and crews' quarters. The inlet branches were so arranged that the air or gas in the holds would be displaced as rapidly as possible. One objection that had been urged against the Harker system was that the flue gas might contain sufficient carbon monoxide to form an explosive mixture with the air in a hold. Dr. Harker's rejoinder to that was that if such a liability to explode existed, it ought to show itself whenever a fireman opened the door of a boiler furnace and allowed a rush of air to mix with the supposed inflammable gases. Yet it was common knowledge that nothing of the kind ever happened. Experiment had shown that not less than 16 per cent. of carbon monoxide must be present in the mixture with the air before explosion was possible, while in ordinary experience the proportion in flue gas never reached even 5 per cent., and was very rarely over 1·5 per cent. In good combustion it was absent altogether. Flue gas was incapable of exploding when mixed with any proportion of air whatever. It had been so largely deprived of oxygen and contained so much inert gas—nitrogen and carbon dioxide—that it might be used to dilute a mixture of explosive gases and prevent ignition.

The flue gas system, the author considered, undoubtedly stood first in effectiveness of operation, because the gas could be delivered into the holds at a much greater rate and the supply kept up for a longer period than the gases used in other systems. A pure CO_2 gas supply was naturally limited to the amount carried in the steel bottles, and SO_2 gas supply was limited by the amount of raw sulphur available, also by its speed of travel in a complicated piping system. There was an important point in this connection, namely, that however well the hatches and ventilators were closed, there was always considerable leakage. For example, at the trials of the s.s. "Fiona," fitted with the Harker system, it was found that about 500 cub. ft. of gas per minute were necessary to maintain a fire-extinctive atmosphere in a large hold of 80,000 cub. ft. capacity. When the hold was filled with gas and the fire under control, it might take several hours before the cargo was sufficiently cooled down to prevent a recurrence of the outbreak. Therefore a current of gas must be kept up so as to carry away the heat from the smouldering mass, and at the same time prevent the inlet of air. If the gas did not reach the burning cargo in sufficient quantity to carry away the heat from the glowing mass, but simply filled up the hold, the effect was the same as if the hatches were shut down, except that the flames disappeared more quickly. In all probability, however, the fire would break out again when the hatch covers were removed. Although no flames were visible, the centre of the burning cargo might be still aglow. The heat from this smouldering mass must be carried away before it was safe to admit air to the hold, and the passage of large volumes of cool extinctive gas was the most effective way. It was this ability to pour any quantity of gas into the hold that made the Harker system so valuable. The Rich system was the least effective, because of the liability of the steam to condense and to the fact that the steam was wanted for propulsion purposes. In promptness of getting to work there was not much to choose between the four systems. Flue gas was always ready, and all that was required was to start a fan and turn on water to the washer. The SO_2 gas system was perhaps the least prompt of the four, because the sulphur had to be lighted up. There was no damage to cargo or hull with either of the systems making use of CO_2 gas, namely, Gronwald's or Harker's. Sulphur dioxide gas and steam were distinctly objectionable from this point of view. All the Harker machines were built to deliver 1,500 cub. ft. of flue gas per minute, and for an ordinary-sized cargo-boat this would require, say, 7 h.p., and the apparatus would cost, say, £350. About the same amount would be required for the 4in. and 6in. diam. piping connecting to the various holds.

THE CHAPMAN GAS PRODUCER.

A new design of gas producer of the rotating type, recently invented by W. V. Chapman, of New York City, presents features of interest. The design is an all-mechanical type, making necessary no manual assistance in firing, in breaking up the fire bed, or in removing the ashes. A section through the machine is shown in the accompanying figure, for which, along with the following description, we are indebted to "Engineering News." It will be seen that fine and coarse coal can be fed simultaneously without separation from a stationary fuel chamber supported at the charging floor by the columns which carry guides for rotating parts. The fuel-chamber capacity is 1,000lbs. of coal—enough to last for about half an hour. The lower edge, which is in contact with the fuel bed of the producer, is water-cooled. The main portion of the shell revolves so that fresh parts of the fire bed are continually coming under the fuel chamber, which feeds sufficient coal to bring the surface up to a level with the bottom of the feed. The lower edge of this fuel chamber is bevelled as shown so as to force down the fresh fuel deposited as the bed revolves away. It is claimed that this action feeds non-uniformly and as needed in the more burned-out spots, checking the formation of holes and crevices in the surface—points at which more fuel is needed than elsewhere. The lower part of the shell, carrying mostly ashes and nearly



Chapman Gas Producer.

burned coal, revolves in the same direction as the main shell, but at a slower speed, so that the fuel bed is continually being sheared apart. This arrangement prevents chimneys and cavities by shearing them off and filling them up as soon as they begin to develop. Since clinkers are formed on the walls of chimneys and cavities, it is claimed that clinker elimination is a consequence of the shearing action which prevents large cavities. Projecting up into the fuel bed from the foundations of the producer is a stationary air distributor and corrugated ash crusher. The lower part of the revolving shell is also corrugated on the inside, and the effect of its rotating about the air distributor and ash head is to crush any lumps which form, allowing them to drop down into the water seal. After the ashes find their way here they are forced out and up by ploughs and are automatically scooped up and discharged.

Three producers are reported to have been in operation since November, 1911, at the works of the American Steel and Wire Company, Cleveland, Ohio. The average results of two weeks' tests on one unit are claimed to have shown 150 B.T.U. per cubic foot, and a maximum variation above and below of but 2·54 per cent. The percentage of CO_2 was 6·54 per cent.; CO was 21·91 per cent.; hydrogen, 17·1 per cent.; CH_4, 2·70 per cent.; and illuminants, 0·51 per cent. It is claimed that much of the success reported is due to care in the design of details; for instance, supporting rollers are chilled castings, ground and running on high-carbon steel pins provided with brass bushings. Separate rollers are used to take side thrusts, and all rollers are mounted in pairs set in equalising yokes. The bearings are provided with large oil wells filled with waste after the scheme for journals on railway cars. The faster travelling gears run in oil.

WROUGHT IRON v. STEEL.

In the course of a paper on "The Manufacture of Wrought Iron and its Future," read at a meeting of the Staffordshire Iron and Steel Institute on Saturday last, Mr. Herbert Pilkington said the manufacture of wrought iron had for many years been considered a dying industry, and one scarcely worth while considering in any light. Puddling furnaces and iron mills had been dismantled wholesale, and until quite recently little or no attempt had been made to improve those plants which had so far survived in this country, and the attempts were of a half-hearted character. Of late a great change had come over the situation, which justified the confidence of those who still had faith in wrought iron contrasted with steel. There was now an immense revival in the demand for wrought iron, because of the appreciation of its marked superiority over steel based on practical experience. In America, a steel country chiefly, there were 141 iron mills in which 20,000 men were employed, and the output was not sufficient to meet the demand, and consumers were importing iron from this and other countries. The world over the future of wrought iron was, he observed, assured, and great improvements were being effected in the rolling mills. All considerations in regard to the manufacture of wrought iron were based on the puddling process—a weak spot. There had been very little change in the practice of puddling since the days of Joseph Hall, of Bloomfield Ironworks, who introduced the pig boiling system in 1839. After describing the fettling process of the furnace, he said that of late years there had been improvements to prevent waste of iron and to alter the character of the product. The process of piling and reheating wrought iron absolutely welded the fibres together, whereas any such shock on mild steel might fracture the whole section very quickly, after the first surface crack occurred, as there was no resistant fibre in the structure. There had been grave mistakes in the application of steel. In the use of wrought iron for fireboxes for locomotives, experience proved that it was far better than steel. A box of the former lasted many years, whereas a steel box after a short service was liable to cracking, which was almost unknown with regard to wrought iron. Other grave mistakes made in the substitution of steel for wrought iron were in the cases of crank shafts for engines, connecting rods, crank pins for locomotives, and also for bolts for pumps and water services. Steel nuts, bolts, and rivets were regarded as mistakes; instances were frequent of heads flying off in practice. In the use of bolts, 90 per cent. of them used in this country were made from wrought iron. For railway wagons the chief coupling links were made of wrought iron, though some people had dreams of steel links. In iron the fibrous nature resisted shocks far better than steel, while steel links would not weld properly and securely.

Increasing the Efficiency of Internal-combustion Engines.—Prof. Watkinson, in his opening address to the members of the Liverpool Engineering Society, said that the efficiency of internal-combustion engines might be increased by the employment of compound expansion. Several attempts at the compounding of internal-combustion engines had already been made; but for various reasons none of them had proved successful. Some preliminary experiments which he had made showed that the compounding of a gas engine with a turbine might be advantageous in connection with large engines. The introduction of the oil engine for marine purposes, instead of diminishing the value of the coal deposits, might lead actually to a great increase by compelling the utilisation of the coal in a more scientific manner by which the tar would be recovered, and the oil obtainable from it would be employed for power purposes. If all the coal consumed in this country were treated in this way it would be possible to obtain from four to eight million tons of oil yearly.

CHAIN DRIVING.*

BY H. T. HILDAGE, M.INST.C.E.

THE transmission of power by chain gearing is a matter which all engineers will probably be compelled to study closely in the near future. Chain gearing combines all the advantages of a positive and highly efficient drive with just as much elasticity as is desirable; it allows, also, almost complete freedom as to the position of the motor, and its distance from the shaft or machine to be driven, which renders it specially useful and convenient. The connecting link between prime movers and line shafts, and between line shafts and machines, in the past has been very much neglected, and is not by any means adequately considered even yet. Steam engine builders, gas engine builders, and electrical engineers have all been striving their utmost to improve the efficiency of the machines they make, but the efficiency of the transmissions between the first mover and the machine to be driven are often the cause of more loss than all the rest of the plant put together. It follows, then, that a means of transmitting power from engine or motor to line shaft or to machine that is quite positive, that will ensure from 96 to 98½ per cent. of the power given off by the motor being transmitted to the machine, and that imposes practically no restrictions as regards the relative positions of the motor and the machine, is one that demands earnest consideration.

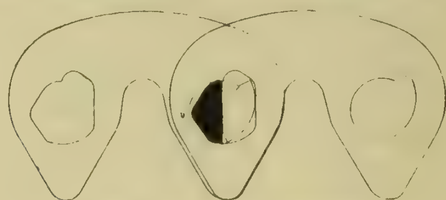


FIG. 1.—MORSE ROCKER JOINT.

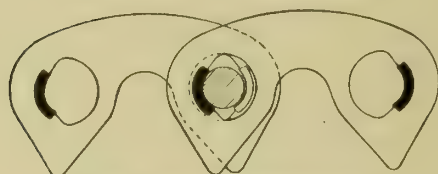


FIG. 2.—RENOLD PATENT LINER.

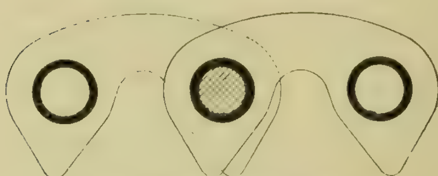


FIG. 3.—PLAIN BUSHED JOINT.

The advantages of chain gearing may be summarised briefly as follows:—

(1) It is a positive transmission inasmuch as the chain cannot slip over the wheels as a belt does. It is elastic, however, since the weight of the chain which hangs between the wheels may act as a spring; lubrication in the bearings and, in certain cases, even the shapes of the links themselves adding to this quality. The effect of this elasticity is to reduce considerably the vibration and noise which is inseparable from a positive power transmission such as spur gearing. It also has the effect of rendering unnecessary the microscopical accuracy of erection and alignment usually essential to produce high efficiency with tooth gearing of any type.

(2) It is highly efficient and the efficiency is maintained until it is completely worn out. Experiments have shown that the efficiency of a well-designed chain drive is somewhere between 96 to 98½ per cent. Tests were made recently, at Faraday House, on a motor-car transmission (that of the 8 to 10 Phœnix motor), consisting of two chain drives and a countershaft. The total loss of power in the two chain drives and the bearing of the countershaft was only 7 per cent. The nature of the action of the chain upon the wheels is such that the high efficiency is maintained until the chain is worn out.

(3) As compared with rope or belt drives, chain gearing is much more economical of space and light. The distance between shafts which is necessary for chain driving never exceeds 8ft. or 9ft., and can, if the circumstances require it, be so small that the chain wheels very nearly touch one another. For this reason, it is even possible to take out a pair of spur wheels, replace them by chain wheels of smaller diameter, and get, as the result, a highly satisfactory drive as regards efficiency and absence of noise and vibration. For overhead factory and shop driving, chains and chain wheels are usually smaller in dimensions than the belts and pulleys which they replace, and as the shafts can be placed so much closer together, it follows that in a workshop dependent on overhead lighting, the interruption of light is very much less with chain gearing than with belting. It even renders possible, in many cases, another form of drive, namely, the placing of line shafts under the floor, with short drives from line shaft to machines. This has been taken advantage of in one or two engineering works and textile factories.

(4) In introducing electrical driving into existing factories it is very often possible, by the use of chain gearing, to use faster-running motors than is the case with belt or rope driving. In order to get ordinarily efficient drives with belts and ropes, it is necessary to use quite large pulleys on the driven shafts, and these cannot always be accommodated. These driven pulleys become very large indeed if the motor is a fast-running motor, and the ratio of reduction a large one. With chain driving a ratio of reduction of 6 : 1 can usually be accommodated with quite small wheels.

(5) There are heavy incidental economies effected by chain driving, partly on account of the advantages above mentioned, partly because it is not necessary that there should be any greater initial tension in the chain than such as is caused by its own weight, and partly on account of the more even turning that is obtained as the result of the drive being positive.

Apart from the chains made up from malleable links, there are two main types of driving chains in common use, namely, the bush roller type and the silent type. Whilst these two types are very dissimilar in appearance, they are not entirely dissimilar in action, and as the main principle of the silent type of chain is also to some extent used in the bush roller type of chain, it will perhaps be as well to take this first.

The silent chain consists of flat plates threaded on studs of some form or other. The plane tooth faces of the links engage with the plane tooth faces of the wheels, and as the chain enters and leaves the wheels with the same peripheral speed as the wheel teeth, and but slightly differing angular velocity, there is very little impact at entering and leaving, and no sliding whatever, in consequence of which the silent chain runs more quietly and more smoothly than any other form of gearing, and it is to this that it owes its name. It is necessary, however, to say that the term "silent" in this connection is merely a comparative one. Some silent chain drives are in truth as nearly silent as could be wished, but others, principally those where small pinions and very high speeds are used, are exceedingly noisy, giving off a loud buzz, which sometimes almost becomes a shriek. The wheel teeth and the chain teeth on engagement and disengagement are moving at the same peripheral speed, but differing angular velocities. The smaller the wheels, the greater will be the difference between the angular velocity of the wheel teeth and the chain, and it is this differing angular velocity that causes what slight impact there is, and is responsible for the noise mentioned. Another advantage of this form of gearing is this: Every type of chain that is made, sooner or later wears in the joints and becomes elongated in pitch. With the silent type of gear, as the bearings of the chain wear and the chain increases in pitch it rides up on the teeth of the wheel and automatically adjusts itself to a larger pitch circle.

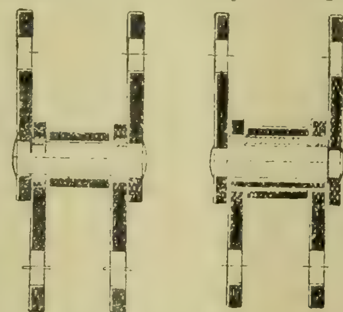


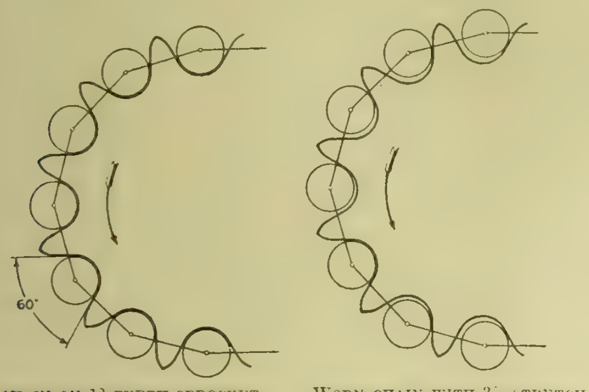
FIG. 4.
Hatched portions show the relative amounts of Bearing Surface in the old Bowl Chain and in the modern Bush Roller Pattern.

When it rises above a certain distance it slips over the tops of the teeth, and it can then be said to be worn out. Up to

* Abstract of paper read before the Rugby Engineering Society, November 19th, 1912.

the point, however, at which it begins to slip over the tops of the teeth, the method of gearing is always the same, and consequently the efficiency of the drive is maintained up to the last. This type of chain lies on the face of a wheel just like a belt, and when the wheels are out of alignment, or the shafts are not parallel, the chain tends to behave exactly as a belt would.

There are several makes of silent chain, the difference between them being principally in the bearings. The object of all is to obtain a bearing that will cause the pitch elongation to be as small as possible, and therefore to prolong the life of the chain as long as possible. The three types are shown on the diagrams (Figs. 1, 2, and 3).



NEW CHAIN ON 12 TEETH SPROCKET. WORN CHAIN WITH 3" STRETCH.
FIG. 5.—ROLLER CHAIN TOOTH FORM.

The Morse Rocker Joint (Fig. 1) consists of a pivot or knife edge which rocks on a plane which is supposed to eliminate all sliding friction, and is said to make it possible for the chain to run at very high speeds without wear taking place or lubrication being necessary.

The second diagram (Fig. 2) shows the Renold patent bearing chain. The bearing in this case consists of a case-hardened steel pin rotating in case-hardened liners which are threaded through the links from one side of the chain to the other, thus providing a bearing surface the whole width of the chain. One advantage of this type is that the pin rotates automatically, and the wear is consequently distributed over its whole circumference, as well as over its whole length.

The third type of bearing (Fig. 3) consists of a glass hard steel bush forced into a plate, running on a case-hardened steel pin. The only advantage of this type is its comparative simplicity, and its cheapness of manufacture. The principal objection to it is that the pressure on the pin, tending to wear it, is only distributed over half its length, since it only bears on alternate sections of the pin. In other words, a chain of this type, as compared with a chain of the liner type, will only have half the bearing area, or will have double the bearing pressure between the bush and the pin when transmitting the same power, and will consequently wear almost twice as fast. On account of this excessive bearing pressure the bush type of chain is exceedingly difficult to lubricate.

It has already been remarked that a silent chain lies on the face of a wheel like a belt, and when the wheels are out of alignment, or the shafts are not parallel, the chain behaves exactly as a belt would. It is natural then at this stage to enquire what means are taken to keep the chain upon the wheels corresponding to the crowning of the pulleys in a belt drive. Silent chains are guided in three ways: (1) By flanging one of the wheels. (2) By a running flange in the chain which runs in a groove on the centre of the wheel. (3) By running flanges on the outside edges of the chain which overlap the edges of the wheel.

Perhaps the most generally satisfactory of these three methods, but certainly the most expensive, is the flanging of the wheels. Any end play in the shafts, or difficulty in aligning the wheels properly, can be allowed for by making the wheels extra wide, and faults in alignment or parallelism do not lead to such rapid destruction of the chain as is the case with other methods of guiding.

The centre guided chain has a solid link inserted in every alternate pitch, and a groove is turned in the wheel, into which this link, or running flange as it may be called, will fit and run. This is a very cheap and very satisfactory method of guiding, and is probably the one that is more generally used than any other. The objections to it are that it requires that the wheels should be carefully lined up and the shafts made parallel, otherwise great stresses are brought to bear on the pins in the chain bearings, and the chain is rapidly racked to pieces. By setting the wheels on any drive out of line a comparatively small amount, it is possible to rack a chain to pieces in a few days, which under ordinary conditions would have given many years' service. The usual practice is to allow ·01in. or ·02in. clearance between the centre guide plate and the grooves, and this is sufficient to render excessive accuracy in lining up unnecessary.

The third method of guiding by outside flanges on the chain is one that is exclusively used by one maker, and occasionally used by others. It has the advantage that it saves the expense of cutting the grooves in the wheels, and the disadvantage that any faults in the alignment of the wheels, or parallélism of the shafts, may force the outside guide plates off the pins and cause the chain to fall to pieces.

The bush roller type of chain is so called because the bearing consists of a pin and bush knuckle joint, with a roller running on the outside of the bush to relieve the friction between the chain and the wheel at entering and leaving. The chain consists of inside and outside elements. An inside element consists of two side plates with two bushes fixed or keyed into them, and two rollers running loose on the bushes. The outside element consists of two side plates with two pins fixed or keyed into them, which pass through the bushes of the inside element. This construction is shown in Fig. 4, which also shows the old type of roller chain. With different makes, the method of fixing the pins and bushes in the side plates is different, but in almost all cases the side plates are made of mild steel, and the pins, bushes, and rollers are made of mild steel, case-hardened. Probably the best and most generally satisfactory method of fixing the pins and bushes in the side plates is by forcing, and then, as far as the pins are concerned, slightly riveting them over. In gearing with the chain wheel, the teeth of the wheel pass between the side plates of the chain and engage with the rollers. The

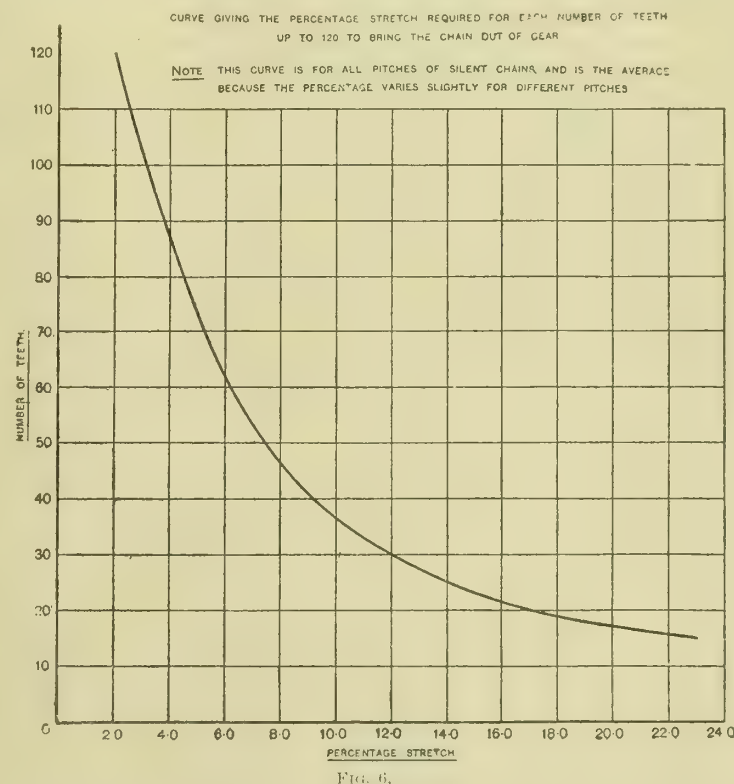


FIG. 6.

exact form of the wheel teeth has been the subject of very careful study, and the resulting tooth form is shown in Fig. 5. It consists of a circular root gap equal in radius to the roller of the chain that is to run on it. The flank angles are about 60°, and the top curves of the teeth vary with each size and pitch of chain. It is not necessary to enter here into a history or discussion of this tooth form, but it may be mentioned that the point of similarity between the bush roller chain and the silent chain lies in the 60° flank. As the chain stretches in pitch the roller rides up this tangent and automatically

adjusts the chain to a larger pitch circle. Of course, when the extension of pitch exceeds a certain amount the chain climbs over the teeth, and can then be considered to be worn out.

It will be seen that the silent chain is a much more delicate piece of mechanism than the bush roller chain, and must consequently be much more delicately handled. As a matter of fact, the bush roller chain is the chain that is always selected for difficult situations, hard service, and rough usage, and under such conditions it is capable of doing wonderful work. The silent chain gives slightly smoother turning, runs much more quietly, and can generally be used at higher speeds. It is the chain that is usually selected for use with electric motors, and for all cases where quiet and smooth running is necessary at moderate speeds.

Table I.

WITH SMALL SPROCKET DRIVING.				WITH SMALL SPROCKET DRIVEN.				
Type. Pitch.	Speed in R.P.M.	Tension for 1in. wide	Min. No. of Teeth Driver.	Min. No. of Teeth Driven	Desirable No. Teeth Driven	Max. P. :	Min. No. Teeth	Speed in R.P.M.
½"	2400	65	13	99	55-75	50	17	3000
⅝"	1800	80	13	109	55 75	65	17	2100
¾"	1200	95	12	115	55 85	75	21	1600
9/10"	1100	120	15	125	55 95	95	25	1200
12/10"	800	160	15	129	55 105	125	29	850
1½"	600	210	17	129	55-115	165	29	650
2"	400	350	17	129	55-115	290	31	450

The roller chain is generally used for low speeds, say, up to about 600ft. per minute. It is also used, however, when the speed is far outside the ordinary range. For example, it is the roller chain that is used for aeroplane work, where the linear speed often exceeds 2,000ft. per minute. The objection to using a silent chain for such cases is its weight, which is undesirable in aeroplanes and airships, and also induces great centrifugal tension and loss of efficiency. The economical limit of speed for silent chains is about 1,300ft. per minute. In special cases this may be exceeded with safety, but not with economy. A little calculation will readily convince one that the tension in the chain increases more rapidly due to centrifugal force, that it diminishes on account of the increase of speed for transmitting a given power.

Table II.

PITCH.	WIDTHS.				H.P. from 1,300 ft. p.m. to 700 ft. p.m.	Bearing Area.	Minimum Breaking Strength	Weight per foot
	CHAIN.		WHEEL.					
	Effective INCH	Overall INCH	Flanged INCH	Grooved INCH		Sq. Ins	Lbs.	Lbs.
·5" Pitch	·65	·8	1·20	·88	·82	·038	1900	·6
	·9	1·06	1·46	1·12	1·22	·057	2850	·8
	1·2	1·32	1·72	1·42	1·64	·077	3800	1·05
	1·4	1·58	1·98	1·62	2·04	·096	4750	1·28
	1·7	1·84	2·24	1·92	2·44	·115	5700	1·5
	1·9	2·10	2·50	2·12	2·84	·132	6650	1·73
	2·4	2·62	3·02	2·62	3·66	·172	8550	2·17
	2·9	3·14	3·54	3·12	4·48	·211	10450	2·63
·625" Pitch	1·0	1·21	1·61	1·23	1·84	·082	3450	1·2
	1·3	1·51	1·91	1·53	2·46	·110	4600	1·54
	1·6	1.81	2·21	1·83	3·07	·137	5700	1·86
	1·9	2·11	2·51	2·13	3·68	·164	6900	2·20
	2·2	2·41	2·81	2·43	4·29	192	8050	2·52
	2·5	2·72	3·11	2·73	4·91	·219	9200	2·84
	3·1	3·32	3·71	3·33	6·14	·274	11500	3·51
	3·7	3·92	4·32	3·93	7·37	·329	13800	4·17

For the silent chain the speed should not exceed about 1,300ft. per minute, and the pinion should always have at least 15 teeth and, if possible, 17 or 19 teeth. With a tooth angle of 60°, which is pretty generally adopted by chain manufacturers, it is possible to cut a pinion having as few as 13 teeth, and such a pinion can be used in extraordinary cases, but for economy, durability, and quietness 17 or 19 teeth are much better.

The driven wheel should not, as a rule, have more than 100 teeth. There is no practical limit, of course, to the number of teeth that can be cut, but a little study will show that the power of the chain to adjust itself to a larger pitch circle, when its pitch has increased by wear, varies inversely with the number of teeth in the wheel.

Let p be the pitch of the chain, and x the increment of pitch after the chain has worn some time, and θ be the angle in degrees between two neighbouring teeth on the wheel. θ will equal $\frac{360}{N}$ where N is the number of teeth in the wheel.

If h be the distance between the position of the chain on the wheel teeth before it has worn, and afterwards, then $x = h.sin\ \theta$, approximately.

The possible rise of the chain on the teeth depends on the depth of the tooth, and is nearly constant for all sizes of wheels of the same pitch. It follows that the maximum amount by which a chain may wear and still remain in gear with the wheel diminishes rapidly as θ diminishes, and consequently as the number of teeth in the wheel increases. This is shown by Fig. 6, which is a curve showing the point at which a worn chain will ride over the tops of the teeth.

Table III.

PITCH	WIDTHS				H.P. from 1,300 ft. p.m. to 700 ft. p.m.	Bearing Area	Minimum Breaking Strength	Weight per foot
	CHAIN		WHEEL					
	Effective INCH	Overall INCH	Flanged INCH	Grooved INCH		Sq. ins	Lbs	Lbs
·75" Pitch	1·1	1 35	1·95	1·43	3·5	.185	3500	1·8
	1·4	1 59	2·19	1·73	4·4	·226	4400	2·2
	1·6	1·84	2 44	1·93	5 1	·268	5250	2·5
·75" Pitch	1·8	2·04	2·64	2·13	5·9	·300	5850	2·8
	2·1	2·36	2·96	2·43	7·0	·354	7000	3·2
	2·4	2·69	3·29	2·73	8·0	·409	8200	3·6
	3·1	3·34	4·01	3·43	10·2	·518	10500	4·5
	3 7	3·99	4 69	4·03	12·3	·626	12900	5·2
	4 4	4·64	5 34	4·73	14·5	·735	15200	6·2
1·0" Pitch	1·3	1·57	2·27	1·65	6·7	·308	5850	2·5
	1·6	1·86	2·56	1·95	8·2	·378	7300	3·0
	1·9	2·14	2·84	2·25	9·6	·445	8750	3·5
1·0" Pitch	2·2	2·52	3·22	2·54	11·6	·536	10400	4·25
	2·6	2·92	3·62	2·94	13·7	·632	12500	4·95
	3·0	3·33	4·03	3·34	15·8	·730	14600	5·65
	3·9	4·14	4·84	4·24	20·0	·923	18700	7·1
	5·1	5·36	6·06	5·44	26·2	1·21	25000	9·2
	6·3	6·58	7·28	6·64	32·7	1·51	31200	11·35
1·25" Pitch	1·6	1·95	2·75	2·06	11·4	·489	9000	4·0
	2·0	2·31	3·11	2·46	14·2	·597	11200	5·0
1·25" Pitch	2·7	2 97	3·82	3·16	18·8	·79	15000	6·5
	3 6	3·94	4·79	4·06	25·5	1·08	21000	8·7
	4·6	4·92	5·77	5·06	32·4	1·37	27000	11·0
	6·1	6·37	7·22	6·56	42·5	1·70	36000	14 5
	7·5	7·83	8·68	7·96	53·0	2·24	45000	18·0
1·5" Pitch	1·8	2·15	2·95	2·27	17·8	·69	12600	5·55
	2·2	2·56	3 36	2·67	21·8	·85	15700	6·65
1·5" Pitch	2·9	3·28	4 08	3·37	28·2	1·10	20400	8·55
	3·9	4·33	5 13	4·37	38·4	1·50	28600	11·4
	5·0	5·38	6·18	5·47	48·6	1·90	36700	14·35
	6·6	6·96	7·76	7·07	64·0	2·50	49000	18·75
	8·2	8·54	9·34	8·67	79·5	3·10	61200	22·75
1·75" Pitch	2·5	2·97	3·77	2·98	30·0	1·11	20400	8·3
	3·1	3·54	4·34	3·58	37·0	1·35	25500	10·3
	4·2	4·97	5·47	4·68	51·0	1·84	35700	14·2
	5·4	5·8	6·60	5·88	64·0	2·33	45900	18·2
	7·1	7·5	8·30	7·58	85·0	3·07	61200	24·0
	8·8	9·2	10·10	9·28	105·0	3·80	76500	29·5
	10·5	10·89	11·80	10·98	125·0	4·54	91800	35·0
	12·2	12·59	13·50	12·68	145·0	5·28	107100	41·0

(Weight per foot: Approximate. H.P. for 1·75" Pitch: From 1,200 to 700 ft. p.m.)

Thus, in the case of silent chain gearing the speed of the shafts, the permissible speed of the chain, and the permissible sizes of the wheels will decide what pitch of chain should be used.

Each pitch of chain is made in various widths, and the width to be used in any specific case is selected nominally on a strength basis. The makers of the Morse rocker chain have found by experience which pitch of chain is capable of satisfactorily transmitting a certain pull per inch of width, this being shown in Table I.

The liner and bush types of chain, however, should be designed with a view to the bearing pressure between the pin and the bush. For a chain that is to run about 1,300ft. per minute, an economical and safe bearing pressure is about 650lbs. per square inch, and this may be increased proportionately as the chain speed is diminished down to 700ft. per minute. It thus follows that each width of chain is capable

of transmitting a certain horse-power between the speeds of 700ft. and 1,300ft. per minute. At lower speeds than these the power to be transmitted should be reduced as the speed is reduced, and also it should be considered whether it would not be wiser to use the bush roller type of chain. The diameters of the pins used, or the bearing area of the chain, made by different makers, can usually be found from their catalogues, or, failing this, calculated from a sample of the chain that it is proposed to use.

Tables II. and III. give the characteristics of the bush and liner silent chains made by Messrs. Hans Renold, Ltd., of Manchester. The bearing areas given in Table II. are obtained by multiplying the projected bearing area of one bush by the number of plates in the weaker combination. The bearing areas given in Table III. represent the total projected area of one liner.

The next consideration is the distance between the centres of the shafts, and here it is not usually a question of deciding upon a suitable distance, but of deciding whether a distance that is fixed by other considerations is, or is not, suitable. Where the centre distance is not fixed by other considerations, however, but has to be arranged, it should be, as a rule, not less than about 50 pitches of the chain selected, *i.e.*, for 1in. pitch chain the centre distance should not usually be less than 4ft., and so on. The effect of reducing the centre distance up to a certain point is to shorten the life of chain proportionately. If the centre distance be shortened beyond this point, the chain life may be shortened at a much greater rate on account of the chain becoming heated, and on account of the extreme difficulty of keeping it properly lubricated. The effect of making the centre distance unduly long, in some cases, is to put a great pull on the bearings. Where the distance between the centres of shafts is unduly short, compensation can be made by using a stronger chain, *i.e.*, by using a chain that will give a lower bearing pressure on the rivets for a given load. If the ratio between the driver and driven wheels is a very large one, the distance between the centres of the shafts should be increased if possible and a stronger chain should be used in order to give a more satisfactory life.

The most economical position for the drive is inclined at from 60° to 80° with the horizontal, and if one wheel is larger than the other, the larger wheel should be above. If possible, the tight or driving side of the chain should be uppermost in horizontal and inclined drives, and if it be not possible, care must be taken to keep the chain well adjusted for tension.

It has already been stated that the roller chain is most suitable for low speeds, that is to say, up to about 600ft. per minute. It can be used on wheels having as few as 8 teeth, and as many as 80 teeth. It is more unsatisfactory to use a roller chain on small pinions at high speeds than to use a silent chain under these conditions, because not only is the roller chain noisier and more severely worn, but there is a decided impact at its entry upon the pinion, and if the pinion be small and the speed high, this impact may be sufficient to cause breakage of the rollers, which is fatal to the chain. The diagram, Fig. 7, is a fair summary of what is good practice with bush roller chain; if anything, it errs on the safe side. It will be seen that this diagram consists of a series of curves, plotted with the chain speed as ordinates and factors of safety as abscissæ. One set of curves, *i.e.*, those having the numbers of teeth marked at one end, show the relations between the speeds and factors of safety of chain of varying pitches. The other set of curves show the range of speeds and the corresponding necessary factors of safety of chains of different pitches. The point of intersection of one of the tooth curves with one of the pitch curves will give the complete safe conditions for a chain of that particular pitch, running on a small wheel with that particular number of teeth. The tendency is to exceed the conditions that are laid down in these curves, but the manner in which this is done should be the subject of careful consideration.

Where any of the limits mentioned for either silent or bush roller chain are going to be exceeded, it is necessary to consider all the conditions of the drive. It is very seldom, indeed, that a drive can be installed under conditions which are ideal in every respect. One drive has a ratio which is rather larger than one would like; another is running at higher speeds; a third has an impulsive load; and in a fourth perhaps the shafts are closer together than they should be, and so it goes. If any drive, however, comes up in which all limitations are exceeded, one has to consider whether it would not be better to find some other way out, or at anyrate, one should balance carefully the advantages and disadvantages of different methods. It should be borne in mind always that the effect of ignoring or exceeding the limitations is not, as a rule, to make the drive a failure from the beginning, but to shorten the life of the chain, that is to say, to make it wear out quickly.

There is probably only one cause that will make a chain drive impossible, and that is a load or turning effort which has rapid and repeated fluctuations. Attempts have been made to overcome this difficulty by means of spring wheels, *i.e.*, wheels with springs between the rim and the boss, which have the effect of smoothing out the fluctuations of torque. This has been found very satisfactory indeed for air pumps,

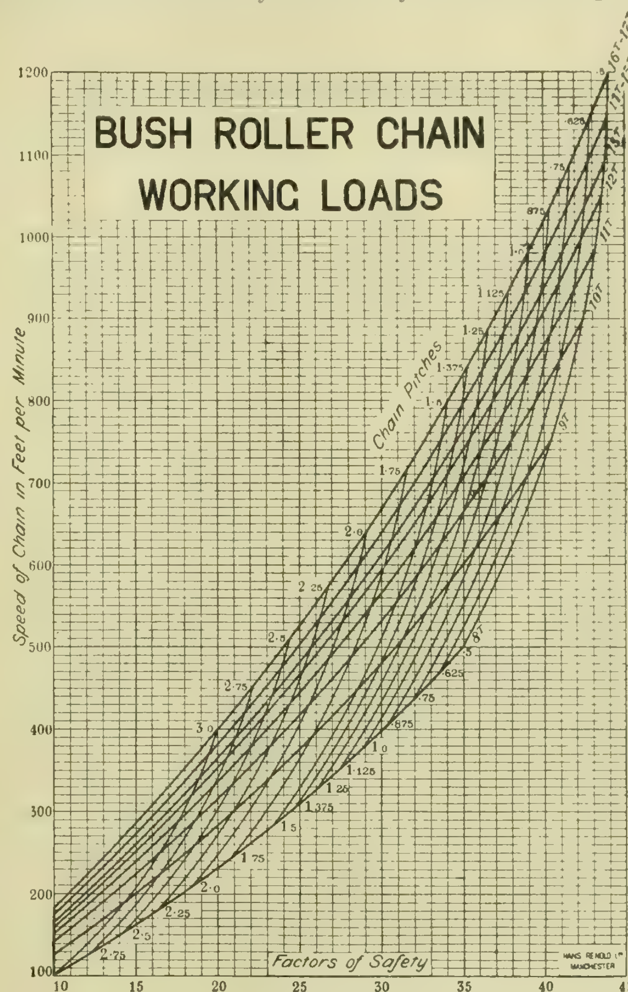


FIG. 7.

but practically useless for slow-running air compressors. The only satisfactory method of driving air compressors and impulsive loads of like nature by chain gearing, so far, has been to provide the compressor with a very heavy flywheel and thus smooth out the fluctuations and to keep the chain tight. Obviously, if the drive is vertical, it is possible to take up all the slack in the chain without having any initial tension in it, and this, therefore, is the most suitable position for fluctuating loads of this kind. As has already been stated, the chain hanging between the wheels in a horizontal drive may act as a spring and help to smooth out fluctuations. The difficulty about it is that its period of vibration is liable to synchronise with the period of the impulses, and then there is a dangerous whipping and snatching of the chain, which wears it out very rapidly indeed. Generally speaking, therefore, drives that involve sudden and repeated fluctuations of load are to be approached very cautiously.

The life of drives, unfortunately, is a subject upon which it is very difficult indeed to give any reliable information. Chain driving has only been in considerable use for a few years, and drives vary in so many points, each of which has its own effect upon the life of the chain, that so far it has not been possible to collect any satisfactory data. The author has under observation, however, a large number of drives, concerning which he is collecting such information as the angular

motion that takes place at each chain joint, the bearing pressure on the pins, and the increase in pitch, and when these observations have been continued for a sufficient length of time, some data will be obtained that will make it possible to predict, with reasonable accuracy, the life of any given chain drive. In the meantime, since these three factors are the only ones that matter, it is always possible to make a comparison between any two drives. The writer has found cases where chains, properly erected and well cared for in the matter of lubrication, have worn out in as short a space as two years, and others that have lasted as long as 14 years. For example, there are a number of chain drives in the Guardian Printing Works, near Stockport, Manchester, which have been running for 12 years, and are still capable of further service. Some chain drives on the governor of a large steam engine were taken off the other day that had been running for 15 years. On the other hand, there were in the works of Messrs. Handiside, of Derby, a number of chain drives on punching and shearing machines which could not be made to last more than two years. As a general rule, the wheels will last about twice as long as the chain in a normal drive. The pinions or small wheels, up to about 25 teeth, are usually made of steel and case-hardened, and the larger wheels should be made from a good grade of hematite iron.

Once the general conditions of the drive are fixed, the only three factors that affect the life of the chain are alignment, adjustment, and lubrication. As has been already stated, faulty and defective alignment may result in the chain being ruined in a very short space of time. Great care should be taken to see that the wheels are in line, and the shafts quite parallel. The chain should be kept in adjustment either by removing a link when it has become excessively slack, or by moving the shafts apart. It is especially necessary to pay attention to adjustment where the drives are vertical or where they are more or less horizontal, but with the slack side of the chain uppermost. Adjustment must also be carefully watched where the load is impulsive. Perhaps the most important factor in the life of a chain, and the one that is most commonly neglected, is lubrication. A few words on this subject may therefore not be out of place. To begin with, chains should always be lubricated on the inside. Oil poured on to the outside of a chain is quite useless because it is flung off by centrifugal force immediately the chain goes round the wheels, and never reaches the bearings. A moderately light grade of machine oil should be used, and the best way to use it is to have it drip on the inside of the chain, near the small wheel. A drip lubricator fitted to drop oil about every minute at one point for every 3in. width of chain, has been found to be perfectly satisfactory in giving thoroughly efficient lubrication. An alternative to this is to encase the drive in an oil bath gear case. This, however, adds to the expense, and is only necessary where the atmosphere is dusty or dirty. Another objection to an oil bath gear case is that one is apt to suppose a chain so enclosed need not be interfered with as long as it runs satisfactorily. It must be remembered, however, that the oil is liable to gum even in a gear case, and the effect of gumming is to prevent the lubricant reaching the pins. The chains should therefore be cleaned periodically with paraffin to remove the dirt, and allow the oil a free passage to the bearings. As showing the importance of efficient lubrication an experiment was made, in which two chain drives, running under exactly the same conditions, were differently lubricated. One was lubricated with an oil can each morning on starting up, and the other was lubricated by a drip lubricator dropping every three minutes. The chain that was automatically lubricated by the drip lubricator lasted just four times as long as the other one. This result has been confirmed and emphasized by later experiments.

BAXTER'S GAS TURBINE.

WE illustrate herewith a design of gas turbine of the type in which the combustion chambers are formed partly in a rotating impact wheel or rotor and partly in a closed case or chamber within which the impact wheel rotates, the invention of Mr. Charles Baxter, 4, Hall Road, Shipley. A is the closed case or stationary chamber inside of which is mounted the cylindrical impact wheel or rotor B. The rotor is secured to the shaft C and is turned true so as to fit the chamber closely both at its periphery and sides, while allowing it sufficient freedom to rotate. The rotor has four pockets D E in it, two pockets D for one direction, and two pockets E for the opposite direction of rotation. The chamber also has pockets F G proceeding from its internal periphery outwards, the axis of the pocket in the rotor and that of the pocket in the outer chamber being substantially in line when a pair of

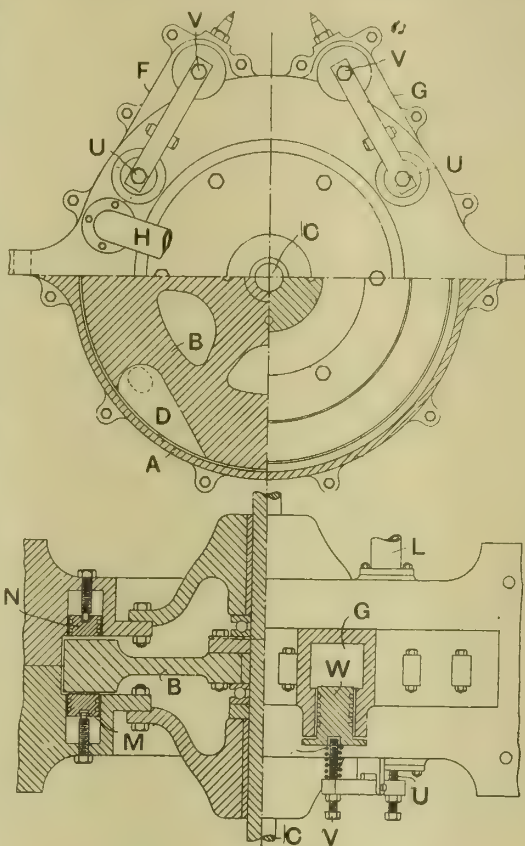


FIG. 1.

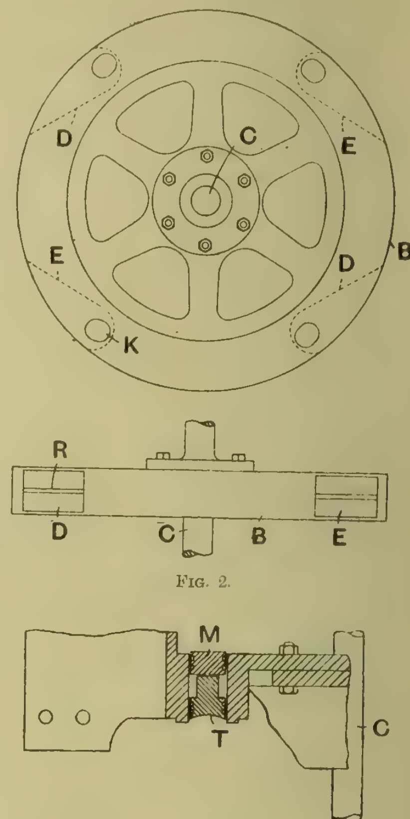


FIG. 2.

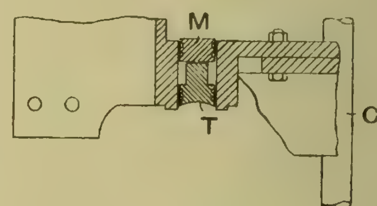


FIG. 3.

BAXTER'S GAS TURBINE.

pockets D and G or E and F come opposite one another. The rotor is operated by the pressure produced by the explosion of a charge consisting of a mixture of gas or vapour and air in the pockets, the explosion taking place when a pocket in the rotor B comes opposite to a pocket in the closed chamber A, and the rotation thereby produced is communicated to the shaft C. The action upon the rotor is analogous to that of a steam turbine, the explosion impinging upon the pocket in the rotor with a force determined by its pressure, and with an effect proportionate to the size of the pockets upon which it acts, also upon the diameter of the revolving wheel or rotor B. The effect is also proportionate to the mass of the charge introduced into the pockets. The charge is compressed at the time of admission, means being provided outside the closed case for compressing the charge. The events in the operation of the engine are as follows: First, charging the pockets with the compressed charge when the pocket in the rotor B comes opposite the pocket in the closed case A, the compression of gas being effected outside the apparatus by a pump or compressor and the charge admitted through a pipe H and through a port K in one side of the rotor B coming into register with the ports in a valve ring M. Second, ignition and explosion of the charge by which motion is imparted to the rotor. Third, exhaust, during which time the products of combustion leave the pockets through ports J and exhaust

pipes L located in the opposite side of the rotor to the inlet ports.

In order to secure close contact between the faces of the rotor and the adjacent faces of the closed case where the ports are, rings M N are provided, fitted into annular recesses in the interior of the closed case at the sides, so as to bear against the adjacent faces of the rotor. In one of these rings is the inlet port O, and in the other the exhaust port P, and these rings are prevented from rotating by pins in the closed case entering holes in the rings. By providing a series of such holes, the rings can be turned and adjusted into such a position as will secure inlet and exhaust taking place at the exact moments required, *i.e.*, bring the ports in the rings into proper relationship with the ports in the rotor. For this purpose the pins are disengaged from one set of holes, the rings turned, and when the right adjustment has been obtained the pins are made to engage with another set of holes.

The thorough scavenging of the pockets of burnt gases is obtained by placing in each pocket D E of the rotor a longitudinal blade or partition R extending the full length of the pocket, and the scavenging agent used is the next following compressed charge of fuel mixture, which is admitted through a port S in the ring M. This being admitted at one side of the pocket, passes along the pocket in a circuitous path first along one side of the partition and from thence by way of the pocket F G passing along the pocket D E at the other side of the partition, driving the burnt gases before it, and filling the pocket with the fresh mixture. The exhaust port P is arranged to open after explosion is completed and the exhaust gases thereby partly escape, but before the exhaust P closes, the inlet port S opens, so that a scavenging of the pocket takes place, immediately after which the exhaust P closes, and this is succeeded by the closing of the port S, hence the burnt gases are driven out, and the pocket is partly charged with explosive mixture. When the port in the pocket reaches the inlet port O again, the charging of the pocket is completed, the fuel being pumped in under pressure or injected and compression of the charge in the pocket takes place. The explosive mixture in the pocket is then ignited by means of an electric spark given off by a sparking plug, the exhaust P opens, and before the exhaust closes, the port S opens so as to drive out the burnt gases from the pocket. To start the engine, if a single engine is used, external force is applied to bring the inlet port in the rotor pocket into register with the inlet port O, and introduce the compressed charge into the pocket, and effect the ignition of the explosion mixture by the sparking plug. This may be done simply by turning the rotor B by extraneous power. If, however, two or more engines be used, each driving the same shaft, the inlet port in each engine may be arranged to alternate with the inlet ports in the others, in which case the collective engines are self-starting, because one of the engines will when at rest always have its inlet port open to the admission of the charge.

The rings M N are kept in close contact with the rotor by placing in each annular groove behind each ported ring a piston T shaped so as to leave space for the admission of the charge through the pipe H and the escape of the exhaust through the pipe L, but adapted to press against the ported ring. Pressing up against each piston T is a rod U secured to one end of a pivoted beam, while the other end of this beam carries a rod V which presses against a piston W working in a cylinder communicating with the pocket F or G, while between the piston W and the pivoted beam is located a spiral spring. When therefore an explosion takes place in the pair of pockets, the force of the explosion forces the piston W outwards, and so through the pivoted beam presses the packing rings M and N inwards against the faces of the rotor, so as to secure a gas-tight joint. When the explosion has taken place the spring forces the piston back to its normal position, and the extreme pressure of the rings M and N against the faces of the rotor is released. These devices keep the ported rings pressed against the faces of the rotor, and any tendency for the ported rings to be blown off the rotor by the explosion of the charge is prevented. The inlet port O is more elongated than the exhaust port P and the scavenging port S. These ports are open and closed by the parts in the rotor where the ports are sliding over the ports in the rings. The inlet pipe H and exhaust pipe L communicate with the respective spaces between the rings and the pistons T, so that the compressed charge enters the space between the pistons and one ring M, and so through the ports into the pockets, while the exhaust from the pockets enters the space between the other ring N and the pistons, and so through the exhaust pipe. In the example illustrated there are two pockets D in the rotor and a corresponding pocket G in the case A for driving the rotor in one direction, and there are two other pockets E in the rotor and a corresponding pocket F in the case for driving the rotor in the other direction. This is for

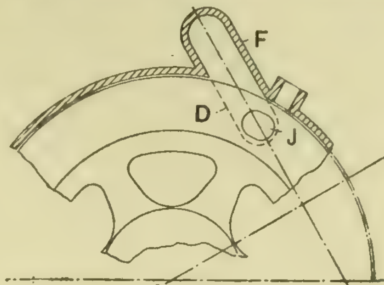


FIG. 4.

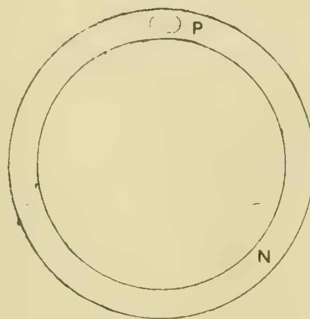


FIG. 5.

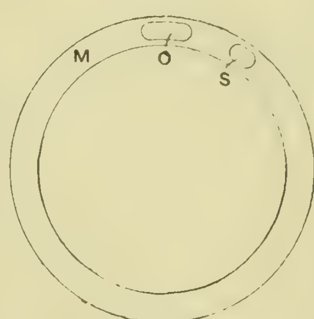


FIG. 6.

BAXTER'S GAS TURBINE.

the purpose of driving the rotor B the reverse way when required. These auxiliary pockets E F are brought into operation by moving the valve rings round so as to secure the necessary altered valve setting for those pockets and putting into operation a separate sparking plug. There may be any suitable number of pockets in the rotor, in which case there are provided a suitable number of pockets in the case all spaced at required intervals apart.

Institute of Marine Engineers.—At the recent annual dinner of this Institute the president, Mr. Summers Hunter, referred to the scheme for erecting city premises for the Institute. Their previous president, the Marquis of Graham, had stated a year ago that £20,000 was required. Six months ago they had in hand about £5,000 in cash and substantial promises, and to-day that sum had reached £5,800. That was sufficient to make a start with. The scheme was a big one, but it had been carefully and patiently worked out. It was perfectly sound and would eventually be successful. He would ask the great shipping industry to respond to their appeals to enable them not only to put up the building, but to have a sum in hand as a nucleus for a capital fund for the good of the Institute.

Failure of a Chain causes Four Deaths.—Through the failure of a chain four men were killed and two others injured at the works of Messrs. Towler & Co., Leeds, on the 20th inst. The chain which broke was at the time of the accident attached to a ladle full of molten steel, which fell at the feet of a gang of men. All but one were caught by the burning metal. At the inquest which was subsequently held, Mr. W. Greaves, metallurgical expert, said the ladle would hold from three to four tons of molten metal, and travelled about 5ft. from the ground. The accident appeared to be due to one of the links of the chain giving way, and then a smaller one doing the same. The links should have been ample for lifting six or seven tons if there were no flaws in them. He had found in one link a faulty weld, and the links appeared to have been forged from a seamy piece of iron. The enquiry was adjourned until to-day (Friday).

INDUSTRIAL AND TRADE NOTES.

Orders for Two Large Battle-ships.—The British Government have, we learn, placed orders for two battle-ships with Clyde builders, viz., the Fairfield Company, Glasgow, and John Brown, Clydebank. The vessels are to be of 27,000 tons displacement, and are to have turbine engines developing 60,000 h.p., giving them a speed of 25 knots. They will carry eight 15in. guns all round, and will be the most costly battle-ships yet designed.

Turbine Steamer for the Canadian Pacific Railway.—There was launched on Saturday last, by the Fairfield Shipbuilding and Engineering Company, of Glasgow, a vessel for the Canadian Pacific Railway. This is a sister ship to the Empress of Russia, launched at Fairfield a short time ago, and is 590ft. in length, 65ft. in breadth, 46ft. in depth, about 15,000 tons gross, and will have a speed of 18 knots, being propelled by steam turbines.

Barrow Demarcation Dispute Settled.—The dispute at Vickers' shipyard, Barrow, has been settled, and the whole of the men have returned to work. Platers had objected to fitters "marking-off" some plates, which work had always been done by platers. After negotiations between the masters and the men's representatives, the firm agreed that the work should be done by platers. These plates were heavy and had been taken to the fitting shop for convenience in handling.

French Iron and Steel Industries.—The "Frankfurter Zeitung" states that there has been a signal improvement in the French iron industry during the past three months, and a considerable extension of business. There is not only a boom in the iron industry in France, but there is every indication that the present is the beginning of a new era so far as regards the organisation and enlargement of French iron and steel works. This is abundantly borne out by the enlargement of works, the installation of new plants, and the modernisation of existing plants. It is noteworthy that scarcely any outside financial assistance is being obtained for carrying out these developments, but that most of the expense entailed is being paid out of current working capital.

Mining Accidents in Northumberland.—Mr. Joseph English, the president of the Northumberland Miners' Association, has published a report of the number of cases in which compensation has been paid for accidents in Northumberland during the past year. The report states that last year was the most serious for the number of accidents Northumberland has ever experienced. There were 10,000 minor cases and 35 fatal accidents. For the minor cases compensation was paid at the rate of £4, and in the fatal cases the average payment was £164, making a total of £45,720 last year. Notwithstanding all their mining legislation there had been an increase of over 100 accidents per week in 12 years.

British Aeroplanes.—Sir George White, at the West of England Aero Club dinner at Bristol on the 21st inst., said the British and Colonial Aeroplane Company had sold flying machines to every European nation, and had erected and equipped a factory and school in Germany. The Italian Government, after their experience with Bristol aeroplanes during the war with Turkey, had declared them to be the best for military purposes, and had placed a first order for 50 monoplanes. An invitation by the Russian military authorities to start a factory in Russia, with promises of large orders, was under consideration. During the year the company had manufactured at Bristol £70,000 worth of machines, of which the British Government had contributed £8,000.

Light Castings Combine.—A combination of manufacturers has been formed, under the style of the National Light Castings Association, and includes the bulk of the manufacturers of such goods as stoves, fireplaces, ranges, railings, &c. It is sought to fix minimum prices below which such goods shall not be sold. Distributors are being divided into four classifications, according to which they will be allowed varying rebates and discounts. Distributors are being invited to sign agreements undertaking not to sell below the minimum prices under penalty of supplies being stopped. Since the manufacturers formed the association the prices of light castings have been advanced by from 40 per cent. to 50 per cent. Meantime, it is stated that a number of capitalists are taking advantage of the new conditions by laying down opposition works for the manufacture of the goods included in the agreement.

Commission Agents and the Insurance Act.—Application having been made to the Insurance Commissioners for the determination under Section 66 of the National Insurance Act of the question whether agents paid by commission or fees who are employed for part time or spare-time service only to canvass for business or to collect moneys, are employed under a contract of service within the meaning of the National Insurance Act, the Commissioners give notice that a hearing of parties interested will take place on Monday, December 9th, at 2-30 p.m., at Wellington House, Buckingham Gate, London, S.W. Any persons interested who desire to be heard before the decision is given should give not less than three days' notice to the Insurance Commissioners of their intention to attend or be represented at the hearing. Statements in writing made by persons affected will be considered if submitted not later than the day preceding that fixed for the hearing.

New African Railway.—A scheme for the construction of a new railway from Tripoli to Central and South Africa, joining the Cape to Cairo line at Stanley Falls, is under consideration. The new line would be about 3,000 miles in length, and would cost about £3,000 a mile, or roughly £10,000,000 altogether. It would run south from Tripoli for about 1,000 miles, thence across the Sahara and Darfur, in French territory, for another thousand miles, and across the Belgian Congo for the last thousand miles to Stanley Falls. In joining the Cape to Cairo line it would form a great highway from Central Africa to the Cape through South Africa, and all the way to the junction of the two lines it would traverse well-known caravan routes. By this line the journey from London to Johannesburg could be completed in a week. It is suggested that if Italy, France, and Belgium guaranteed the interest on the cost of construction as far as the line ran through their respective territories the capital could easily be obtained.

Parsons Petrol Engine Set for Arc Welding.—The Parsons Motor Company, Ltd., Town Quay, Southampton, have recently supplied one of their 42 h.p. 6-cylinder petrol engines, coupled to dynamo and exciter, to a well-known firm who carry out work in the leading ports covering arc welding jobs of all descriptions. The conditions under which such a plant have to work are most arduous. The engine must be equal to continuous full-power work for long periods, and yet must be extremely closely governed as between no load and full load suddenly applied. To this end the firm have designed a special vertical enclosed sensitive governor, which is driven by enclosed gearing at the forward end of the engine, and claim with this governor a variation of only about 5 per cent. on an output of 200 amperes. at 70-110 volts. The electrical equipment was furnished by the Lancashire Dynamo Company. At the present moment the firm have orders in hand for an exactly similar set, but with the engine of the paraffin type, this being for a well known firm of shipbuilders; and one for a 4-cylinder engine, also of the paraffin type, for a shipyard on the Continent.

The Light Railways Bill and Trackless Trolley Systems.—In the House of Commons on the 18th inst. the Light Railways Bill, as amended in Standing Committee, was considered. Mr. J. M. Robertson (Parliamentary Secretary, Board of Trade), on behalf of the Government, moved the omission of Clause 2, which empowers the Light Railway Commissioners to authorise trackless trolley systems. He said the clause as amended in Committee cast a heavy liability on the promoters of trackless trolley systems in regard to the roads, and it was regarded by the tramway interest as being an evil so great that they would rather have no provision made for trackless trolley systems at all. The effect of the omission of the clause would be that the law in relation to trackless trolley systems would remain as it was now. It seemed to the Government that it was preferable that questions of road maintenance should be dealt with in a general, comprehensive, and systematic manner rather than in such a piecemeal fashion as was the case in this measure. The omission of the clause was agreed to, and the Bill was read a third time without a division.

A German Coal Research Laboratory.—The German Society for the Advancement of Sciences has decided upon an important step in the interests of the utilisation of the coal production of this country. It will establish a special institute for coal research at Mülheim (on the Ruhr). The cost of the building, which is estimated at £35,000, will be defrayed by the Mülheim authorities, who will also present the site. The annual budget of the institute will amount to £6,000, and as the Rhenish Westphalian Coal Industry Syndicate has agreed to contribute £5,000 per annum the society will only have to find the comparatively small sum of £1,000 a year. The building of the institute is to be begun next spring, and it is expected that it will be completed by the spring of 1914. Among the specific problems that will be pursued will be the study of the production of coke under altered conditions, and the obtaining of tar, water gas, and power gas, or the transference of inferior products of tar distillation into more valuable fluid or gaseous fuel substances, in which Germany is very poor, so that this country may be made independent of the importation of such substances from abroad. Furthermore, old and unsolved problems, which

seem more tractable with the modern aids of physical and chemical methods, will again be taken in hand, such as the direct production of electricity from coal.

Shipbuilders and the New Agreement.—An important conference was held in Edinburgh on the 20th inst between the Shipbuilding trades, excluding boilermakers, to discuss the draft of the proposed new agreement. It was decided provisionally to adopt the draft, which will now be submitted to the men concerned to vote for or against its acceptance. The new agreement is an amalgamation of the principal provisions of the National Agreement of March, 1909, and the Supplementary Agreement of December, 1910, with a number of amendments designed for the purpose of making the machinery for settling disputes without stoppages of work operate more smoothly. Under the new agreement definite times are fixed within which all questions raised must be dealt with, in consultation between men and individual employers, by a local joint committee, by a local conference, or by a national conference, so that it is expected that one of the objections of the men to the old agreement—that under it much time was lost in the consideration of disputes—will be removed. The penal clauses, providing for the punishment of employers or men who broke the agreement, have been dropped, and so has the provision for the appointment of an outside arbiter to decide when there was a breach of agreement, while the men have withdrawn their proposal that there should be a neutral chairman at joint conferences. A few verbal alterations were made on the draft agreement, principally for the purpose of making certain points more explicit, but there were no changes of importance.

The "Responsibility" of Trade Unions.—Messrs. Vacher & Sons, of Westminster, the appellants in the recent momentous trade union case, have issued the following statement: "The judgment of the House of Lords in the case of Vacher & Sons, Ltd., *v.* The London Society of Compositors, that under no circumstances, and whether a trade dispute is in contemplation or not, can a trade union be made responsible for its tortious acts, vitally affects every employer in the land. Henceforth labour can, even without cause, black list any firm in the country, and employers are powerless to defend themselves. Labour can announce broadcast that Messrs. A. & B. do not pay trade union rates, and gravely injure the firm by proclaiming their output to be the work of blacklegs, even if such be not actually the case. But labour can, and probably will, do much more than that. They can announce that Messrs. A. & B. are black-listed, and by threatening other firms that they will call out their workers if they do business with Messrs. A. & B., they can ruin any concern as and when they please without hindrance or redress. The decision of the House of Lords in its interpretation of the Trades Disputes Act (1906) thus places a new and intolerable power in the hands of vindictive labour leaders. It must surely be clear, not merely to every employer, but also to every lover of fair play, that the Trades Disputes Act must be repealed. We have made our fight, and we are confident that other employers will not stand aloof in our resolve to cope with the new industrial crisis in an immediate and practical way. We ask for generous support for the Trade Disputes Act Reform League. We are convinced that it is only through the agency of this League that employers can obtain justice, and in our view strong financial support for this organisation is a first-rate form of insurance."

Record Shipbuilding.—The quarterly report of the Shipconstructive and Shipwrights' Association recently issued, referring to shipbuilding output states that "notwithstanding the enormous output which has been recorded during the previous quarters of this year, the return for the quarter ended September constitutes a record. All the large shipbuilding centre participated in the share of the increased tonnage. The result of this is the continuance of good employment over all departments of our membership in every part of the country, so much so that we cannot, in some places, meet the demand for the labour of our members, especially on the Clyde and in his Majesty's dockyards. There is every prospect of this condition of things continuing for some time to come, and we trust and urge that every member will take the fullest advantage which full employment offers to husband their resources, as the present extraordinary output of shipbuilding will sooner or later have its effect on the tonnage of the world, when the inevitable depression will follow." The report further states: "During the quarter there have been a number of minor stoppages in various places, and some of them of a somewhat irritating nature, and which, we think, with a little consideration and reasonableness on both sides, might have been avoided. In the interests of all members no stoppages of work must take place until every effort has been made to reach a settlement. There is no use of an organisation whatever, if members will not carry out their own general rules, and give the officials an opportunity of endeavouring to adjust these grievances. Such procedure is in direct opposition to collective bargaining—which is the basis of our organisation. It is far better for the members to use the machinery of their organisation to have their grievances redressed than by hasty and precipitated stoppages of work, that, in the end, settle nothing, and only entail unnecessary loss on the part of the individual members and friction in the administration of the Association."

Safety of Mines: Important Case to Colliery Proprietors.—A case of importance to colliery proprietors was recently decided at Doncaster Police Court, when, after a hearing extending over six hours, the Bentley Colliery Company were fined for not withdrawing men from the mine when there was found to be $2\frac{1}{2}$ per cent. of inflammable gas in it. The prosecutor was Mr. Mottram, His Majesty's Chief Mining Inspector for Yorkshire and the North Midlands District, acting under Home Office instructions. Two offences were alleged against the Coal Mines Act, namely, that the pit was improperly ventilated and that the men were not withdrawn, but it was only possible to deal with the latter charge that day, the other case being adjourned till November 30th. The prosecution alleged that on July 30th, when one of His Majesty's Inspectors of Mines visited Bentley Colliery, he smelt gas, and his safety lamp revealed more than $2\frac{1}{2}$ per cent. in the main airway. Men were doing ripping there, and, although the under-manager's attention was drawn to the circumstance, the men were not withdrawn, as required by Act of Parliament. The defence was that the men employed in the return air-way were there for the purpose of repair work and not for getting coal, that they were ripping in order to improve ventilation, and that Section 67, under which the prosecution was taken, permitted their presence. The firm had conducted collieries in the district for 150 years, and had never been proceeded against before. They had voluntarily undertaken work which the Home Office would be better employed in undertaking than in indulging in prosecutions of this sort. Together with the Brondsworth and Denaby Colliery, they were employing the very best men in the world of science to advise them in regard to gob fires and other mining problems. Notwithstanding this defence the Bench imposed a fine of 20s. and costs.

British Engineers' Association.—The British Engineers' Association, which was incorporated on April 26th of this year under a certificate from the Board of Trade, and was brought into being for the purpose of promoting the interests of British engineering firms in China, has developed considerably since that date. The Association does not carry on trade of any sort, is in no sense of the word a profit-making concern, and is unconnected with any business concern or other association. This Association now comprises a large number of the very best engineering firms in Great Britain. The president is Mr. Douglas Vickers: the vice-presidents are Sir Robert Hadfield, F.R.S., Mr Herbert Marshall, the Right Hon. Sir William Mather, P.C., LL.D., Mr. C. C. Scott, and Sir John I. Thornycroft, LL.D., F.R.S. The chairman of the Executive Committee is Mr Wilfrid Stokes. Already the Association has made arrangements for the collection of valuable first-hand information on the subjects which affect engineering interests in China, and is issuing it in the form of confidential reports to its members at frequent intervals. Among the many important items in the programme of the Association is an endeavour to make the British Government, the banks, the shipping companies, and every one else concerned, realise that it is their duty to study and promote the interests of British manufacturing engineers. Another important feature in the policy of the Association is the encouragement of the education of Oriental engineers in the British language and on British lines, whether by British engineering schools in the countries concerned or by facilities at the educational establishments and in the engineering works of Great Britain. The Association is devoting its attention exclusively to China at the present day because that is the country where, above all others, British engineering interests are in most urgent need of support. When thoroughly organised to cover the ground efficiently, the Association will turn its attention to any other country where British engineering interests may be suffering. It is interesting to note that applications have already been received to extend the influence of the Association to Canada, South America, Africa, Australia, Mexico, and elsewhere. The offices of the Association are at Caxton House, Westminster, and the secretary is Mr. Stafford Ransome.

The Shelf Boiler Explosion.—The formal investigation ordered by the Board of Trade in respect to the Shelf boiler explosion is fixed for hearing in the Town Hall, Bradford, Yorkshire, on Tuesday, December 3rd, at 11 a.m.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Treatment of iron or steel for preventing oxidation or rusting. Richards. 17563.
Process for the commercial utilisation of peat. Testrup, Rigby, and Söderlund. 17610.
Treatment of sulphide ores. Ashcroft. 24170.
Steam superheaters. Doettloff & Thomsen. 24241.
Carburetters for internal-combustion engines. Wolseley Tool and Motor Car Company and Remington. 24316.
Draught-controlling devices for steam superheaters fitted to locomotive boilers. Toussaint & Doettloff. 24579.
Chain-driven change-speed gearing. Hans Renold, Ltd., and Simpson. 24597.
Automatic turning machines for cast metal hollow-ware. Thomas Holcroft & Sons, Ltd., Holcroft, and Challen. 24750.
Valves for internal-combustion engines. Clark. 24808.
Internal-combustion engines. Forbes. 25266.
Manufacture of petrol gas for lighting purposes. Harsant, and Mitchelite Petrol Air Gas System Company. 25334.
Elastic fluid turbines. Warwick Machinery Company (1908) (Curtis). 25349.
Valves of the double-beat type. Hill & Vivian. 25544.
Valves of internal-combustion engines. Knowles. 25888.
Tube-cleaning lathe. Pecinka. 26435.
Piston packings. Reading. 26878.
Driving mechanisms. Cake. 27098.
Casting apparatus. Pauly. 27390.
Variable-speed gearing. Triumph Cycle Company, and Franklin. 27499.
Burners for gaseous, liquid, and solid combustibles. Gautreau. 28009.
Starting mechanism for internal-combustion engines. Christensen and Boult. 28284.

1912.

Tube and bolt vices. Bauer. 1268.
Manufacture of expanded metal and apparatus therefor. Expanded Metal Company & Salmon. 2227.
Power hack saws for metal. Humpage. 2241.
Liquid fuel burners for oil-fired furnaces. Laing. 2546.
Valves for blowing engines and compressors. Walker, Walker, and Walker. 2767.
Hydraulic valves. Sir W. G. Armstrong, Whitworth, & Co., and Davy. 2952.
Rolling of round bars of metal. Barge. 3616.
Starting valve-gear for internal-combustion motors. Romeyn. 4209.
Automatic railway signalling devices. Mokossenyi & Schieren. 4266.
Manufacturing and refining copper alloys. Rocky & Eldridge. 4409.
Process of fusing and purifying copper. Rockey & Eldridge. 4410.
Conveyers. Michener. 4805.
Process for sinking shafts or driving tunnels. Allgemeine Tiefbohr & Schachtbau Akt.-Ges. 5306.
Apparatus for spraying or ejecting liquids. Blake & Blake Bros., Ltd. 5943.
Adapters or couplings for flexible metallic tubing. Smith. 6465.
Smoke-consuming devices. Bolgiano. 6875.
Change-speed and reversible transmission mechanisms. Campbell. 7334.
Railway rail joints. Tieche, Meier, & Russell. 7440.
Carburetters for internal-combustion engines. Wood. 7741.
Lathe headstock. Werner. 7837.
Vices. Joh. Manegold Nachf. 9474.
Revoluble grate for gas generators. Deutsche Huttenbau-Ges. 9589.
Regenerators or hot-blast stoves. Schroeder & Reinhard. 10154.
Machines for cutting metal bars. Butler. 10400.
Furnace grates. Werger. 11590.
Universal coupling for transmission shafts. Constantinescu. 13107.
Lock nuts. Schrader. 13979.
Steam traps. Abels. 15290.
Crucibles used in metallurgical furnaces. Brayshaw & Brayshaw. 15628.
Sound-quenching apparatus for the exhaust gases of explosion motors. Vogt. 15737.
Water-tube steam generators. L. & C. Steinmuller. 16057.
White-metal bearings. Putz. 18789.
Metallic propellers. Jacomy & Jahan. 18838.
Grinding and polishing machines. Böhringer. 19735.
Water-cooled fire-bars. Grabowsky. 21380.

ELECTRICAL, 1911.

System and apparatus for preparing perforated tape for telegraphic transmission of messages. Ingram. 10973.
Electric timing devices. Hatfield. 24141.
Miners' electric lamps. Hailwood. 24305.
Hand-feed arc lamps. Kamm. 24333.
Electric distribution systems. Partridge. 24386.
Processes for producing directive forces by induction in alternating-current apparatus. Abraham & Carpentier. 24442.
Dynamos. British Thomson-Houston Company, Ltd., and Whitaker. 24463.
Apparatus for obtaining a uniform longitudinal seam in tubes welded by electricity. Ges. fur Elektrotechnische Industrie. 24575.
Controlling apparatus for electrical lifts. A. W. Penrose & Co., and Barlow. 24745.
Miners' electric safety lamps. Oldham. 24787.
Electrical measuring instruments of the induction type. North. 25086.
Electric heating of ovens. Martin. 26101.
Electric switches. Siemens Bros. Dynamo Works, and Crowley. 26245.
Holders for electric lamps. Frankenburg & Sons, Ltd., and Fleming. 26376.
Incandescent electric lamps. Ludecke & Brimsdown Lamp Works, Ltd. 27263.
Materials for dynamo brushes, shaft, and other bearings. British Thomson-Houston Company. 27621.
Combined electrical switch and resistance or current graduating device. Dimming Switches, Ltd., and Barber. 29231.

1912.

Automatic tension regulators for shunt dynamos. Gallay. 1539.
Telephones. Shardlow. 1721.
Protected electric fuse blocks. Price & Callendars Cable and Construction Company. 2380.
Method of supporting the commutators of dynamos. Jones. 3282.
Continuity of electric conduit systems. Railing & Taylor. 3179.
Automatic telephone systems. Baum. 6305.
Selective electric signalling on telephone exchange party lines. Crook. 6640.
Lamp pillars for electric lighting. Southall. 7056.
Semi-automatic telephone systems. Siemens & Halske Akt.-Ges. 10444 and 11464.
Devices for protecting telegraph lines against inductive action from neighbouring circuits. Moll & Kuschewitz. 12764.
Automatic cut-out for electric lines. Michaelsen. 13428.
Sparking plugs. Farina. 14251.
Vacuum tube lighting. Markiewicz. 14864.
Electric radiators. Nightingall. 16506.
Compensation of single-phase potential regulators. Akt.-Ges. Brown, Boveri, et Cie. 18107.
Wireless telegraph transmitters. Shaw. 18111.
Arc lamps. Kamm. 23155.

METAL QUOTATIONS.

TUESDAY, NOVEMBER 26TH.

Aluminium ingot	90/- per cwt.
„ wire, according to sizes, &c. ......from	112/- „
„ sheets „ „ ...... „	120/- „
Antimony ......£39/-/- to	£40/-/- per ton.
Brass, rolled	9⅛d. per lb.
„ tubes (brazed)	11½d.
„ „ (solid drawn)	9¾d.
„ „ wire	9⅛d.
Copper, Standard	£76/12/6 per ton.
Iron, Cleveland	67/9 „
„ Scotch	73/9 „
Lead, English	£18/7/6 „
„ Foreign (soft)	£18/-/- „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£8/12/6 per bottle
Silver	29⅛d. per oz.
Spelter	£26/5/- per ton.
Tin, block	£226/15/- „
Tin plates	15/4½ „
Zinc sheets (Silesian)	£31/5/- „
„ (Stettin; Vieille Montagne)	£31/10/- „



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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Diesel Engine Troubles.

THE Diesel engine, notwithstanding its high thermal efficiency and extensive adoption in many directions, has some special troubles of its own, as we are reminded by some observations on the breakdown of an engine of this kind recorded in the current issue of "Vulcan." The engine was of the 3-cylinder type with cylinders 17in. diam. by 2ft. stroke and developed 236 h.p. at 180 revs., and the breakdown, which resulted in the practical smash up of the engine, was due to the sudden seizure of the piston and cylinder while running under ordinary working conditions. The disquieting feature of the breakdown is that it is one of several of the same type which the Vulcan Insurance Company have experienced within a comparatively short period. In April last our contemporary gave particulars of a similar breakdown, and that again had followed closely on the failure of a sister engine at the same place and from the same cause. Further, we have reason to know this is only a repetition of the experience of others, and it is this fact which is disquieting, for an engine which is liable to sudden smash without apparent cause has a serious blemish on its character in the eyes of power users, to whom reliable and continuous running is a primary essential. The question is, How is this sudden seizure of piston and cylinder brought about? At present it must be admitted it is not an easy one to answer. Several explanations are put forward, but it is difficult to say what credence should be respectively attached to them. In all multiple-cylinder engines it is obvious that in the event of the friction of one cylinder becoming excessive it is overcome by the normal or increased power of the other cylinders. The engine is not slowed down as it is when there is only a single cylinder, and in this respect it might be argued that the multiple-cylinder Diesel is only like the multiple-cylinder steam engine. Such, however, is not the case, for owing to the extremely fine clearances between the piston and cylinder in the Diesel engine necessary for its high compression, seizure is liable to occur much sooner than

in a steam engine, and when it does take place something must go, owing to the momentum of the flywheel and other moving parts. Usually the connecting rod is doubled up or broken and the crank shaft twisted, and more often than not the cylinder is smashed also. At present the clearance space is only a few thousandths of an inch and does not exceed in some cases the expansion due to a difference of temperature of more than 100° Fah. In other words, a rise of 100° Fah. in the temperature of the piston above that of the cylinder would cause seizure. Such a margin, as our contemporary remarks, is very small, and the possibility of increasing it will have to be seriously considered by makers of Diesel engines if they are to acquire the reputation for reliability necessary to secure the confidence of power users. At present a little falling off in quality of the lubricating oil or the presence of gritty matter in the fuel oil would appear almost sufficient to produce trouble, apart from the irregular expansion between piston and cylinder, which it is suggested may take place owing to the fact of the cylinder being water cooled while the piston—at all events in the smaller sizes—is not. Another suggested explanation of seizure trouble is that it may possibly be due to a slight growth of the piston resulting from repeated heatings and coolings. This, we know, is a well-known phenomena in cast iron when heated to high temperatures and depends to some extent on the composition of the iron. To what extent it may occur in a Diesel engine is a matter for enquiry. We believe growth of this kind has been recorded with superheated steam, and the temperature inside Diesel cylinders is much higher than this. Of course if the clearance spaces could be increased materially the trouble indicated would be overcome, but the suggestion is easier to make than to adopt successfully. Only those who have had practical experience in the compression of air to between 500lbs. and 600lbs. on the inch can realise what perfect workmanship in cylinder and piston is necessary to obtain this result and how greatly leakage difficulties increase with increase of clearance space. However, the matter cannot well be allowed to rest where it is, and though the problem is a serious one we doubt not Diesel engine builders will eventually solve it. Nothing at all events can be gained by hiding the facts, and a full presentation of them is the first step to a solution of the troubles at present arising out of them.

Patents and Inventions.

It is much easier to point out a social imperfection or injustice than it is to find a remedy, and we are reminded of this somewhat trite adage by some observations of Mr. A. M. Taylor at the recent opening meeting of the Birmingham section of the Institution of Electrical Engineers, on the relations between inventors and the British Patent Office. Mr. Taylor displays a sympathy with inventors with which most people will agree, and it is only when we come to consider his remedies that one realises how difficult it is to make perfect law. That commercial prosperity may be largely stimulated by the ingenuity of inventors, and hence it is desirable to encourage them, goes without saying. It is equally evident that there is a temptation for large concerns with abundance of capital and control of certain markets to stifle competition from new developments, and with this object it not infrequently happens that huge monopolies purchase inventions in their early stages simply with a view to their being smothered or kept secret, and so defeating the very object for which protection is granted, viz., that of making "patent" new ways and means of effecting given results with a view to the prosperity of a nation as a whole, the limited monopoly granted to the inventor being, in fact, the State reward for his revelation. Mr. Taylor takes exception, as many others do, to the inadequate proof of novelty which at present is attached to a British patent, and which leads capitalists and manufacturers to regard most of them with apathy until their originality has been decided in a court of law, as most inventions have to be sooner or later. He contrasts this with the greater encouragement which he claims is accorded in the United States and Germany, as a consequence of the greater thoroughness of search into the questions of anticipation and originality, and which even if it involves delay, does at least inspire a belief when a patent is granted that it is not likely to be upset by a judgment in the law courts, though it may be desirable to observe here that litigation is not unknown in either of the two countries named, nor in either is the granting of a patent a "guarantee" of validity.

A more important criticism, especially to poor inventors, is the more reasonable nature of the fees that are charged by the Patent Office for the work it undertakes and the protection it affords. In Germany, for instance, he points out that the only fee which the inventor has to pay in order to secure a thorough search is about £1; a further £1. 10s. it is true is required, but this is not called for until the patent is granted. Again, in respect to the life of a patent, the contrast is to our disadvantage. In the United States the term is 17 years, and the average annual cost throughout this period is 8s. 6d. In Great Britain the term is 14 years, and the annual cost works out at an average of £7. 2s. 10d. One result of this is that about two-thirds of the patents granted lapse after the fourth year. A good deal of misconception prevails as to what is adequate subject matter for a patent, and the common impression that a combination of known ideas may provide sufficient basis is, as was proved in the recent Ilgner case in the law courts, erroneous. Mr. Taylor's suggestion with a view to encouraging invention is that the Patent Office should be invested with powers to determine authoritatively whether an invention possesses subject matter before issuing a patent, and it is impossible to review many of the specifications that are issued without feeling that fees have been extracted and "protection" accorded for ideas that are "as old as the hills," but here again it is easier to recognise what seems a flagrant defect than to suggest a satisfactory remedy, and we can easily understand the disinclination of a Government department to accept the responsibility proposed, while if it were thrust upon them it would endow them with powers which inventors subject to its exercise might deem at times more autocratic and, possibly, unjust than those occasionally attributed to the law courts.

The question as to what amount of control a manufacturing firm should exercise over the ideas of employés respecting improvements in work or methods on which they are daily engaged is one that has often been discussed, and an unfair view is sometimes taken from both sides. The inventor sometimes forgets that but for the special experience he enjoys the opportunity of making improvements would not be presented to him, and, on the other hand, the manufacturer sometimes thinks, very unreasonably, that this privilege is the sole incentive to improvement. Certainly we think no fair-minded person would agree that the signing of a document which calls upon employés to hand over absolutely to the firm engaging them all inventions they may make while in their service is fair or conducive to progress.

The suggestion that the period of six months between the lodging of a provisional application and of a complete specification should be extended is a matter of opinion. It

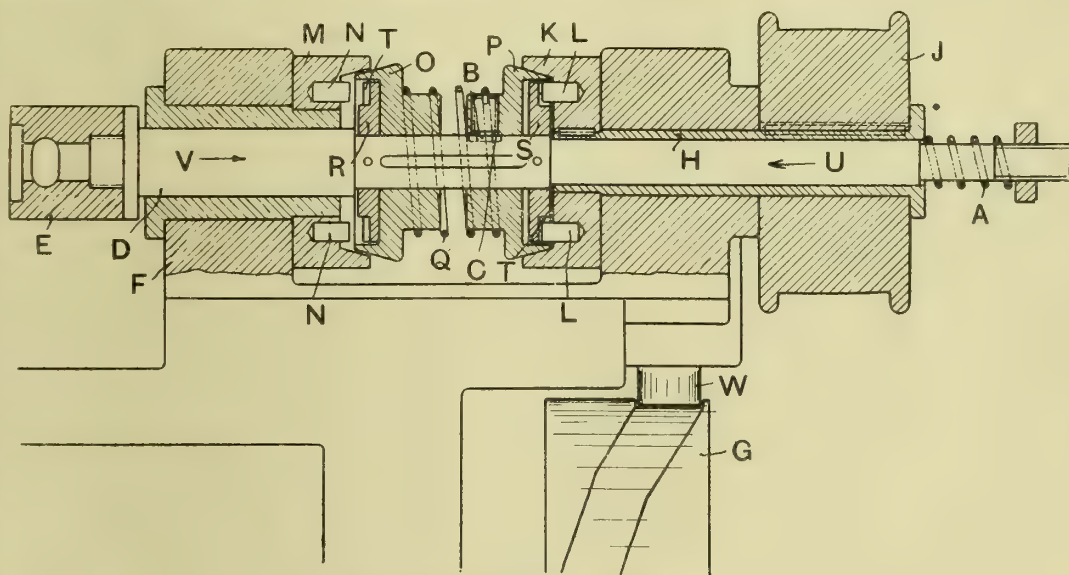
may be in some cases that the time is too short for the necessary investigation and experiment which are desirable for the latter, and a few months' extension would be advantageous. At the same time, it is obviously not in the public interest that this interval should be too prolonged, for it must not be forgotten that unless a complete specification is issued the provisional is not published, and during the period of its existence it acts as a secret block to other inventors. Whatever the length of period, there would be some inventors who would contend it was too short. The suggestion also that two or more independent ideas are combined to produce a new result should be held to be subject matter for patent, but that in such cases the patent should only be granted for a limited and shorter period than the usual complete patent, with a view to encourage this kind of invention, will not, we think, appeal to many. It makes a somewhat invidious discrimination to begin with, and implies that the short term granted for a "sort of invention," and for this reason would probably be as unacceptable to patentees as the arbitrary powers which would have to be exercised would be to the officials concerned.

SCREW-CUTTING GEAR FOR TURRET LATHES.

In screw-cutting gear for turret lathes, the spindle carrying the screw-cutting head must rotate at a higher speed than the work pieces when cutting the screw thread, and, further, when the screw thread has been cut the screw-cutting head must be rotated more slowly than the work piece, or be stationary. The stopping of the spindle carrying the screw-cutting gear has hitherto been effected either by means of claw clutches or by friction clutches connected with the driving mechanism. In the construction under notice, the invention of Messrs. Ludw. Loewe & Co., Huttenstrasse, 17/19, Berlin, N.W., 87, Germany, friction clutches in combination with direct or positive clutches are employed in such a manner that the latter clutches are automatically brought into operation by the backward and forward movements of the spindle carrying the screw-cutting gear after the driving or braking of the screw-cutting spindle has already been initiated by the friction clutches. Such an arrangement has, it is claimed, the advantage of ensuring a positive engagement between the clutching parts and of preventing at the same time excessive impact between these parts, which impact, if unchecked, would be liable to set up undue stresses in the various parts concerned.

In this arrangement, which is shown in the accompanying sectional view, the spindle D is adapted to be driven from the belt pulley J mounted upon a sleeve H, which carries at its forward end a block K having a conical recess therein and provided upon its inner face with driving pins L. A similar block M is fixed to the slide F, and is provided upon its inner face with driving pins N. Mounted upon the spindle D in such a manner as to be slidable thereon but to be rotated thereby are two cones O and P, between which is arranged a spring Q adapted to force the cones apart. Annular driving collars R and S are fixedly secured upon the spindle D, and formed with recesses T in which the driving studs L and N respectively are adapted to engage when the screw-cutting spindle D is to be driven or stopped. The cone P is provided with a pin B adapted to engage in a slot C in the spindle D, this slot permitting of a limited relative movement in axial direction between the cone P and the spindle D, so as to allow the ring S which is fixed to the spindle to come into positive engagement with the pins L after the members P and K of the friction clutch have come into engagement with each other. A spring A provided on the spindle D serves to keep the coupling members P and S in engagement with the coupling members K and P respectively when the latter are driven from the pulley J.

The action of the apparatus will be readily understood from the following description: When the spindle D is moved by the cam drum G in the direction of the arrow U the parts of the clutch are in the position shown in the drawing. When the cutting of the screw is completed the cam drum G returns the slide F to its initial position, but since the screw-cutting head E is in engagement with the work piece the spindle D is thereby held from movement, with the result that the hollow cone M comes into engagement with the block O and thus causes the braking or stopping of the rotation of the spindle, as the uncoupling of the cones K and P and the driving ring S and studs L simultaneously takes place. Immediately after the braking or stopping of the spindle D has been effected by the friction clutch O, the further backward movement of the slide F and consequently of the coned block M causes the driving pins N to enter the recesses T of the driver R, whereby a positive or direct coupling is effected between the stopping device and the screw-cutting spindle. Consequently the screw-cutting head or tool is positively held stationary, whereupon it is unscrewed from the work piece in the usual manner. The coupling of the screw-cutting spindle to the driving devices, that is, to the coned block K, is effected in a similar manner. In the forward movement of the slide F due to the cam drum G the cone P is brought into engagement with the cone K, so that the spindle D is driven from the belt pulley J. At the moment when the screw-cutting tool meets the work piece the continued forward movement of the slide F with the cone K causes the spindle D to move relatively in the direction of the arrow V, whereby the spring Q is compressed and the driving ring S is brought into engagement with the driving studs L, so that the screw-cutting spindle is driven in a positive manner as soon as the screw-cutting tool comes into operation.



SCREW-CUTTING GEAR FOR TURRET LATHES.

The Institution of Heating and Ventilating Engineers.—This Institution offers two heating studentships, tenable in the faculty of engineering at University College, London, each of the value of £50 a year, together with 11 guineas for payment of college fees. The object of these studentships is to encourage research in heating and ventilating engineering. Candidates must produce evidence that they have already pursued a course of engineering training, and are familiar with the work of an engineering laboratory. Full particulars may be obtained from the Secretary, University College, London.

THE ELECTRIC FURNACE FOR BRASS MELTING.*

BY G. H. CLAMER AND CARL HERING.

WITH the rapid development of the electric furnace the question is often asked whether it is applicable to brass melting. This question cannot be answered in a general way with a simple yes or no, because so much depends on local conditions, especially on the cost of electric power, on the particular furnace used, and on the specific requirements. It was thought best therefore to give in the present paper a general discussion of the various factors involved, including what data there is available, from which a better idea may then be obtained of the applicability of the electric furnace to any specific case.

In general, it may be said at the start that the cost of the electric energy is by no means the only important factor, nor necessarily the most important one, as there are other advantages of the electric over the fuel furnace, which may be of equal and even greater importance and money value. The final verdict of course is the usual one, "does it pay," and therefore all the factors which make up the final cost should be duly considered.

A crude idea of the cost of heat produced in different ways is shown by the following figures, and for simplicity in comparison and calculations all the data in this paper, whether it refers to heat or any other form of energy, will be given in terms of the more convenient and more universal unit, kilowatt-hours, that is, 1,000 watt-hours; a British thermal unit is equal to 0·29303 (approximately 5/17) watt-hour, and a kilogram calorie to 1·1628 (approximately 7/16) watt-hours; or one watt-hour equals 3·4127 (approximately 17/5) thermal units, or 0·85998 (approximately 6/7) kilogram calorie.

Assuming that all the energy from the following original sources is converted into useful heat, then 1 kilowatt-hour in the form of heat will cost as follows:—

	cents
From electric power at 1 cent per horse-power hour...	1·34
From water power at $20 per kilowatt year (Niagara Falls)	0·228
From water power at $6 per kilowatt year (Norway)	0·0670
From wood at $4 per cord	0·0525
From coke at $4 per gross ton	0·0479
From crude oil at 2 cents per gallon	0·0457
From coal at $3 per ton	0·0292

With such a large difference in the costs of the original sources it is evident that to be cheaper than fuel heat, electric heating must possess other and more important advantages of money value.

In a good electric furnace nearly all of the energy is converted into useful heat in the metal, while in a fuel furnace by far the greater part, probably about nine-tenths, goes up the chimney as waste, and this becomes worse the higher the temperature of the metal (as the chimney gases must necessarily always be considerably hotter than the metal which they have heated or else they would not have imparted their heat to it. With the electric furnace there are no chimney gases, hence no corresponding losses). In some electric furnaces nearly all of the best of the heat goes into the metal directly, being generated in it, no matter whether the temperature is high or low, hence the efficiency of this part of the operation is nearly perfect.

A comparison of the mere costs of a unit of heat from different sources is not by any means a true criterion; moreover with fuel heat the cost of the useful heat is largely a matter of temperature also, as the losses become far greater the higher the temperature. With the electric furnace this is not the case, the efficiency of the production of useful heat being practically independent of the temperature. Many of the objectionable features of fuel heating, such as oxidation, volatilisation of the zinc, absorption of sulphur, &c., do not begin until a certain temperature is reached; hence if the cold metal is preheated by the hot gases of fuel heat to this temperature before it enters the electric furnace, the advantage of each of the two methods of heating may be profitably combined. The writers are of the opinion that this combination, consisting of a preheating of the cold charge by fuel heat, and then developing the higher temperature by electric energy will be the method of the future in the economical use of the electric furnace for brass melting, when the cost of the electric energy is relatively high.

This preheating method is quite different from the often proposed simultaneous heating by fuel and electric energy combined, that is, by adding fuel heat over the top of the charge in an electric furnace. In the latter case many of the objectionable features of fuel heat still exist, hence many of the advantages of electric heating would be lost, and moreover the best forms of design of a furnace for a fuel and for electric heating are so different that they cannot be combined to the best advantage. In an electric furnace the upper surface of the metal and the space above it should be made as small as possible, while for fuel heating, both should be made larger to provide for a combustion chamber and a large heating surface. Nevertheless in such furnaces in which the liquid metal is heated electrically from the bottom and the cold metal is charged on top of it, important advantages might still be gained by such a combination.

There is another advantage of this preheating. When a hot piece of metal falls into melted metal it is more easily wetted by the liquid metal than when cold, and when thus wetted it takes up the heat from the liquid with remarkable rapidity, far quicker than metals take heat from hot gases. This means that the melting of a charge is accomplished more quickly, which in turn means a greater output per day from a given furnace, or a smaller furnace for a given daily output, hence less plant charges. Also less idle time for the labourers, and less loss of zinc, as the metal is held liquid during less time.

One of the important advantages of some of the electric furnaces is that they can be forced, that is, that large amounts of heat can be forced into a relatively small furnace quickly; in fact, it is actually running the furnace to better advantage to do so, as the heat losses from the outside of the furnace are thereby reduced per pound of charge because the time during which that pound is being heated is less. This again means less plant for a given daily output, less loss of time and attendants, and less loss of zinc.

Electric energy purchased from large power plants always costs less if used continuously during 24 hours of the day; and moreover, considerable heat is used in first heating up a cold furnace, although this may sometimes be done with fuel heat. Hence, whenever practicable, it is far more advantageous to operate an electric furnace continuously 24 hours per day; this is more important with electric than with fuel furnaces. Another saving in electric furnaces, which may be taken advantage of whenever possible, is in being able to use a lower furnace temperature (hence involving less loss of zinc) by casting directly from a tilting furnace by bringing the moulds to the furnace. This saves the excess of temperature necessary to supply the loss of heat in the pouring ladle, as also the labour cost of handling this ladle.

One of the great advantages of the electric furnace is that the metal may be melted entirely in a non-oxidising atmosphere; in fact, if some charcoal is added the atmosphere in the furnace may even be made reducing. There is therefore less loss of metal by oxidation, in fact, there ought to be none at all, and possibly even a recovery of some of that which was oxidised. The value of the metal thus saved may be greater than the cost of the electric energy. This non-oxidation also means that such raw materials as finely subdivided metals like borings, grindings, fine concentrates, &c., which cannot be satisfactorily handled in fuel furnaces can be readily melted because they will flow together more easily, which in fuel furnaces can be accomplished only with fluxes and these, besides involving a first cost and the cost of the heat for melting them attack the crucible and the metal in them is lost as oxides in the slag. In reverberatory, and especially in cupola furnaces these losses of metal are increased still more, due to the mechanical loss of fine particles which are carried off by the rapidly moving gases; also to the greater loss of zinc owing to the excessively high temperatures and the longer time required during which the zinc loss continues. According to the Bassett 6 per cent. of the zinc in brass is lost by vaporisation in the melting and casting of brass for rolling for a 2 to 1 brass, this means about 2 per cent. by weight of the original brass. When the furnace is closed, as is possible with an electric furnace, this ought to be mostly saved.

Owing to the absence of contact with the fuel gases in an electric as distinguished from reverberatory furnace, there is

* Abstract of paper read before the American Institute of Metals, September 24th to 27th, 1912.

also less contamination of the metal by sulphur and other objectionable fumes; and with the absence of the sulphur there is a greater fluidity of the metal, hence there will be less castings that are faulty and a greater freedom from blow-holes. Another advantage lies in doing away with the crucibles. Against this is the cost of relining the electric furnace, but this is negligibly small in comparison, except arc furnaces, in which the repairs of the roof are an important item, owing to the very intense heat to which it is exposed.

In those forms of electric furnaces in which there is an agitation of the liquid metal, as distinguished from a quiet melt, there will also be a better mixture of the metal, that is, a greater uniformity, and in one of the forms of electric furnaces mentioned below, in which there is a continuous strong upward flow of the heated liquid metal, like the rising water in a rapidly boiling kettle, all of the metal in turn is forced repeatedly to the top, hence any mechanically suspended particles of dirt will be rapidly brought to the top with it, and as these are always higher than the metal they will stay at the top where they can be skimmed off with the slag. There will therefore be a mechanical cleaning or refining similar to that which would be produced by gravity if the metal were kept at rest for some time, while hot, but with this forced upward flow it is done far more rapidly, economically, and presumably more perfectly, and there is therefore less loss of zinc which continues as long as the metal is kept hot. As it is possible to reach a higher temperature more quickly, hence also with less losses of zinc, greater fluidity may be obtained, hence sharper castings. The temperature can be very easily controlled in an electric furnace and there is therefore no reason why there should ever be any waste due to excessive heating. It could be controlled so closely that uniformity in the castings as far as it is governed by temperature ought to be easily obtained.

Finally, there is the factor of convenience and cleanliness; no coal bins—no handling of coal and ashes, no making fires; no waiting for fires to become hot, no chimney, &c. And as there are no exposed flames, as the outside of a well-built electric furnace ought not to be more than warm, there is the important factor of the comfort of the workman. The above will give a general idea of the advantages to be derived from electric over fuel furnaces for brass melting, exclusive of the cost of the source of the heat. These have more or less money value depending upon the particular conditions of the plant and the nature of the castings, and this money value should be taken into consideration, as it is one of the important factors.

The following data, deduced from the presumably reliable figures for the specific and latent heats, give the energy required to melt and superheat (about 10 per cent.) 100lbs. of the corresponding metals, assuming there are no losses of heat. They should be accepted only as approximations.

	Kw. per 100lbs.
Aluminium	13·9
Nickel	12·
Copper	8·7
Brass 80 : 20	8·2
Brass 2 : 1	6·9
Bronze	6·9
Platinum	5·6
Zinc	4·1
Tin	1·6
Lead	0·91

The apparently large discrepancy between aluminium and platinum is due to the fact that the former is a very light metal and the latter a very heavy one. Although no great precision is claimed for these figures, yet they are believed to be sufficiently accurate that any claims made for melting with appreciably less than these theoretical minimums may safely be taken as impossibilities. Such claims have been published to advertise furnaces. The following figures, compiled from various presumably reliable sources, give the actual consumption in fuel furnaces per 100lbs. of metal:—

Brass—
- 1·8 gall. of oil
- 18lbs. coke improved furnaces forced draught
- 50lbs. coke old type pit furnace
- 40lbs. anthracite
- 45lbs. coke given as usual practice

Bronze—
- 3·8 galls. of oil
- 3·0 galls. of oil

Electric furnaces may be divided into general classes, arc and resistance. In the former the heat is generated in an electric arc formed in a short space between the electrode usually of carbon or graphite and either the metal, the slag, or another electrode. The heat is generated mostly in the arc itself and only part at the electrodes; hence the heating is entirely from the top and must therefore flow down into the liquid metal by conduction, which takes time; it may be said that heat does not like to flow down in liquids. Moreover, the heating is mostly by radiation from the arc or by the contact of the vapours from the arc, hence the transmission of heat to the metal is limited in speed largely to this radiation and cannot be forced; moreover, the roof of the hearth is also subjected to these very high temperatures.

The temperature of this arc is that of the vaporisation point of carbon and is therefore extremely high, over 3,000° C. (5,432° Fah.), which is high enough to volatilise all metals. It is therefore excessive, and the metals ought not to be directly subjected to it. Hence an arc from carbon to non-ferrous metals is likely to cause serious losses of the metals by vaporisation, especially of the zinc in the brass. In all arc furnaces the carbon must be moved forward as it burns away, and when the arc goes out it must be started again by a movement of the electrode, hence they require continuous attention. In one type of furnace the arc is produced between an electrode of carbon and thick blanket of slag which covers the metal. In this way it heats the slag chiefly by radiation and the metal beneath receives its heat entirely from the hotter slag. A transmission in a downward direction which is necessarily limited in speed and cannot be forced except by heating the slag to a much higher temperature than the metal. The energy used in heating this slag should be taken into consideration, as it is probably not small. Very good results in brass melting are reported to have been obtained from this type of furnace.

Another method is to heat the interior of the walls of the furnace with the arc and then revolve the whole furnace so as to bring the metal over the heated walls. Although ingenious, it also seems a slow process which cannot be forced and involves greater losses through the walls, as they must be heated to a much higher temperature than that required by the metal. Another method is to heat by radiation alone, by having the arc entirely above the metal and between two carbons. Good results have been claimed for such a furnace for brass, although the zinc loss was probably somewhat excessive. Moreover, it cannot be as easily forced as a resistance furnace, and the roof is likely to give trouble owing to the excessively high temperatures.

In the resistance type furnace the heat is generated by passing the electric current through a solid or liquid. The only practicable ones for brass melting seem to be those in which the current passes through the liquid metal itself or through the slag. The well-known induction furnace is of the type, but as we believe it has not been applied to any extent to brass, it needs no further comment here. It seems that brass has too low an electrical resistance for successful operation These furnaces are in successful use for steel, which has a higher resistance.

In another type the heat is generated in a moderately high vertical column of material like slag or glass over the hearth by passing the current through it by means of electrodes. The cold metal is then placed on the top of this liquid and is melted as it descends through it. It has been in apparently successful use for fine concentrates, but we do not know of its having been used for brass. Large pieces would be likely to sink through before they are melted and we understand that there is danger of the charge freezing in the bottom.

In another type of resistance furnace with which the writers have been experimenting and which they are now developing and expect to soon place in commercial operation, small portions of the liquid metal are heated with great rapidity in cylindrical holes in the bottom of the hearth and then ejected at once with considerable force into the main body of the molten liquid, fresh metal being continuously sucked into these holes. The time in which each particle is heated and ejected is probably only a fraction of a second. This ejecting is produced by a peculiar recently discovered electromagnetic force called "pinch effect." All the heat in the furnace is therefore generated directly in the metal itself exactly where it is wanted, hence with no initial loss at all, that is, with perfect efficiency; it therefore reaches the metal

instantaneously instead of by the slow process of conduction and radiation. The highest temperature is moreover in the liquid metal itself where it is wanted, as distinguished from being above it or in the slag; and the heating is done at the bottom of the liquid which is the more rational place, as heated metal always rises. The only losses occur after the heat has been in the metal, being those through the walls and the top surface; there should be no loss of furnace heat through the electrodes, although there will of course be some loss of electrical energy in them. All of these losses can be made small by proper designing, hence this furnace promises to be very efficient. It has the further great advantage that it can be forced to as high a degree as desired, that is, the heat can be generated in the metal in very great quantity and therefore the heating can be done rapidly, hence a small furnace can be made to have a large daily output, and, therefore, also less loss of heat per pound of metal.

The furnace is started with a small charge of molten metal or from a small portion of the frozen metal left in it from the previous charge, and the melting is done by charging the solid metal into the superheated liquid metal, by which method the heat is transmitted with very great rapidity to the solid metal, especially if the latter has been preheated by hot and reducing gases so that it becomes wetted by the liquid.

The systematic and quite pronounced upward circulation of the hot metal which is ejected from the heating holes in this furnace brings all the metal repeatedly to the surface where the suspended impurities and dirt are set free and can therefore be easily removed as they collect, thus purifying the metal mechanically by what has been designated as a "boiling action." This circulation also mixes the charge very thoroughly, thus making the metal homogeneous.

Various metals and alloys like brass, bronze, iron, steel, nickel steel, &c., have been melted in this furnace very rapidly and with a remarkably high heat efficiency considering the crudeness of the experimental furnaces and their small sizes. The results of the preliminary tests are now so satisfactory and encouraging that a moderately large furnace for melting bronzes and another for steel are about to be constructed and will soon be in commercial operation.

VAGARIES OF ENGINEERING PRACTICE.

THIS subject was dealt with in a paper read before the Liverpool Engineering Society, by Mr. J. Hamilton Gibson, who confined his remarks to a consideration of the ordinary multitubular marine boilers and reciprocating engines as fitted on board an intermediate ocean liner of 8,000 h.p. to 10,000 h.p. In making up an estimate, one of the first considerations was, he observed, to make due allowances for all the novelties, and a few years' experience in overhauling specifications revealed an amazing diversity of practice. Some would insist on each cylinder standing by itself, the column tops being braced together by fore and aft girders, others preferred all the cylinders to be bolted together, forming a continuous solid mass from end to end; or, again, the cylinders might be bolted together in pairs. Each case called for special treatment in design and erection to ensure an equal satisfactory result. Then why should one firm insist on liners in the high and intermediate cylinders, while another specified liners in the low-pressure cylinders only? When the fitting of liners was adapted to form steam jackets, the object was entirely laudatory, but surely, if it was merely a question of wear, the simplest method was to make the cylinder walls $\frac{1}{4}$in. thicker to allow for reboring if and when necessary. Reboring, however, should be unnecessary if the right piston packing was used. There were many ingenious spring packings in existence, which were no doubt necessary to allow for slight inaccuracies in the bore of casings, or carelessness in erection; but in these days of precision as regards machine tools it should not be imperative to legislate for such inaccuracies. Some engineers, in fact, preferred an absolutely solid piston valve, on the score that if it was made a good working fit at first it should and must work all right for an indefinite period, any slight leakage being taken up and obviated by the low-pressure slide valves. A very good compromise was effected by the adoption of the so-called "split-solid" packing rings, which, however, required to be adjusted with extreme care.

On the general question of bearing surface, guide surface, and thrust surface there was, he said, great diversity of opinion, and the same remark applied to the scantlings of working parts. When these proportions were specified in hard and fast figures they usually erred on the side of excess. It could not be denied, however, that excessive weight and excessive surface represented bad engineering and bad design. The perfect engine was like the perfect chain, each part and each link proportioned for the work it might be called upon to perform without superfluity of material or excess of weight. The engine-builder, by long years of experience in all classes of work, accumulated data which enabled him to apply the appropriate material and the appropriate stresses to engines for battle-ships and torpedo-boats, for ocean liners and tramps, for tug-boats and channel steamers, for stern wheelers and large paddle-boats, all differing in degree, but all suitable and fit for the purpose and all self-sufficient for their duty; and it was galling when in the working out of his designs he was forced so to modify his practice that the harmony of the whole arrangement was spoilt by exorbitant demands in one or more directions which introduced heavy links, to the detriment of the complete chain. There was only one link in the chain where excessive precaution was justified, and that was the crane hook, the tail end—in other words, the propeller shaft of an engine. Here the stresses might be so enormous, and were so indeterminate, and the consequences of mishap so serious, that anybody could be excused for adding an extra inch "on his own" after the designer and the Board of Trade and Lloyd's and all the rest of them had done their utmost. If a rule might be laid down for general guidance in engine design it would be this: Find out exactly what was required to be done, and what were the precise conditions of the service, and then design an engine having the fewest number of parts, the fewest number of joints, and the fewest number of accessories possible to attain the desired result.

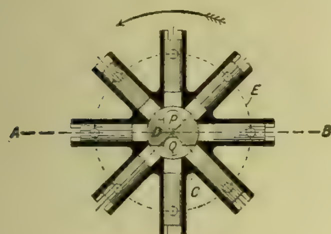
In the design of boilers there were, he said, fewer vagaries to grumble at. The Board of Trade, Lloyd's Registry, and other authorities had drawn up full and comprehensive rules which must be strictly adhered to, and admitted of very little latitude; and if boilers were well and truly made to one or other of the rules laid down there was not much to choose between them as regards efficiency and upkeep. Almost more so than in an engine, a boiler should be of uniform strength and stiffness throughout so as not to throw an undue stress on any one part. In other words, it should be free to "breathe" in every direction. The corrugated furnace principle fulfilled this condition perfectly in a longitudinal direction. Some superintendents, however, insisted on "roofing" stays, tying the combustion chamber tops to the shell—especially in double-ended boilers. In this case the Board of Trade required the combustion chamber bottoms to be tied to the shell also, thus making a more or less rigid connection from top to bottom, which often led to trouble.

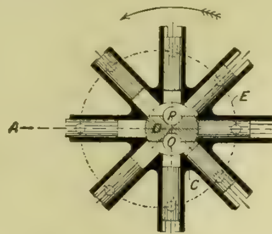
From the point of view of standardisation, he considered that the prevailing practice of obtaining auxiliary engines and pumps and apparatus from outside firms had much to recommend it. The air pump was the last of the auxiliaries to fall into the hands of outside makers, the turning engine and an occasional reversing engine being about all that was left for the main engine-builder to exercise his ingenuity upon. For some reasons this evolution was to be regretted, but from the standpoint of interchangeability and standardisation of practice it was a distinct gain—for the auxiliary engine-maker especially, because he was in a splendid position to fix standard sizes and lavish all his care on the perfection of details. The worst feature of standardising engineering practice was that it made it difficult to introduce improvements, and on the whole, perhaps, it was just as well that there were clients who were willing to order machinery that required fresh designs every time.

New Dock at North Shields.—Messrs. Smith's Dock Company, Ltd., opened their new dock at North Shields on Tuesday last, when the large twin-screw steamer "Iroquois," belonging to the Anglo-American Oil Company, of London, was safely docked. The dock is 525ft. long, and the entrance is 71ft. wide. It is specially equipped for dealing with large oil-tank steamers.

INTERNATIONAL ENGINEERING AND MACHINERY EXHIBITION, OLYMPIA.—IX.

Messrs. Compayne, Ltd., of 64, Victoria Street, Westminster, London, S.W., had a working exhibit of Hele-Shaw pumps and hydraulic motors, showing how, by their means, power may be variably transmitted. The system provides extraordinary flexibility in regard to variation of speed and effort between the prime mover and the work to be performed, and works with a high efficiency (exceeding 90 per cent.). The pump, which forms the keynote of the system, is the invention of Dr. Hele-Shaw, F.R.S., and is of the rotary, plunger type, positive in action, reversible, and of variable capacity. It can be rotated at high speeds, and consists essentially in the combination of an inner case revolving freely on ball or roller bearings with a simple form of central cylindrical valve. This invention enables the pump, while working at a high speed, to give immediately great hydraulic pressures, a common maximum pressure of the pumps being 2,000lbs. per square inch. At the same time the pump is perfectly balanced, is compact and simple to construct, and is of moderate cost and weight. The pump shown at the Exhibition was used to raise and lower a large weight, and it could be seen with what ease this could be accomplished, and the delicacy of control obtained. A larger pump was also exhibited to show the internal construction.





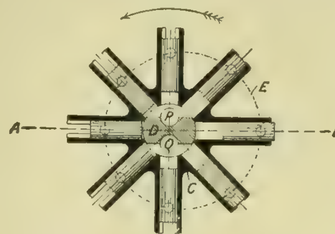


FIG. 1. FIG. 2. FIG. 3.
DIAGRAMMATIC VIEWS, SHOWING VALVE ACTION AND STROKE-REVERSING EFFECT OF HELE-SHAW PUMP.

Figs. 1, 2, and 3 show diagrammatically a section through the centre of the pump at right angles to its axis. In these figures, however, an essential and most important part of the pump is purposely omitted. This essential part upon which the high efficiency of the pump largely depends, and which is called the "floating guide ring" or "floating ring" is afterwards described and shown by means of Figs. 4, 5, 6, and 7. A B is the line along which stroke variation takes place. C is the "cylinder body" in which are formed a number of radial cylinders. This body is coupled to and driven directly by the prime mover employed. D is the central valve, or "D" tube on which the cylinder body revolves and in which are the induction and eduction ports P and Q, communicating with the outside by passages. The radial cylinders are fitted with pistons, through each of which, parallel with the axis of D, is a gudgeon pin. On these pins are fitted slippers which work in an annular groove, so that the pin centres are constrained to follow a circular path E, as shown in dotted lines, the position of which can be changed by moving its centre along the line A B. Suppose the cylinder body to be rotating in the direction of the arrows, and the position of the circular path to be such that its centre coincides with the centre of D as in the first figure, no radial motion is communicated to the pistons. If the position of the centre E be now moved to the left as in the second figure, the pistons above the centre recede from D, and tend to form a vacuum, so that the oil (the working fluid) is forced either by atmospheric pressure (or by artificial pressure in the supply tank) through port P, whilst the pistons below the centre approach D, and discharge liquid through port Q. If the position of the centre of E be now moved to the right as in the third figure, then the pistons below the centre recede from D, and liquid is drawn in at Q, whilst P becomes a delivery port. The flow of liquid has therefore been reversed without altering the direction of rotation.

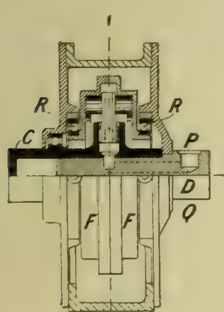
These diagrams also show that the stroke of each piston is twice the distance between the centre of the valve D and the centre of the path E, and that any stroke from zero to the maximum can be given on each side of the central position, the delivery being varied in rate and direction simply by the alteration of the position of the path E. The flow or discharge is thus seen to be proportional to the eccentricity of the circle E. In moving from the extreme position on one side to that on the other, the discharge is gradually reduced until in the central position it is zero, after which it again increases but in the opposite direction to the maximum, so that the change from full forward discharge to full reverse discharge is made without shock.

Figs. 1, 2, and 3 show, for simplicity, an arrangement in which 8 cylinders are employed, but an odd number of cylinders is almost always used as giving the most satisfactory results in practice, seven being adopted as the standard number for most purposes.

Figs. 4, 5, 6, and 7, which show a standard pump, indicate the variation from the diagrammatic form.

Fig. 4 shows the section along the centre line of the central valve or "D" tube in the upper half of the figure, and the lower half of the figure shows the outside of a revolving circular hollow drum F, the object of which will be explained, but which rotates freely in the empty casing; Fig. 5 shows a section on the centre line of the cylinders, that is, at right angles to the axis of the "D" tube; Fig. 6 shows the guiding slippers in position, having one side of the drum F removed; and Fig. 7 shows the guides, the cover of the case being removed.

The "D" tube, which acts as a fixed spindle, is the same as in the diagrammatic form, and the cylinder body is also similar, but has 7 pistons; these latter being fitted with gudgeon pins, so that any tangential pressure is borne directly on the cylinder wall. Both ends of the gudgeon pins pass through slots in the cylinder wall, and on each end is a slipper fitting in a circular groove in the inside of the revolving drum F. The drum F (the floating guide ring) can be moved to and fro along A B, but is allowed to rotate freelv on the ball or roller bearings R R, which latter are carried by the guide blocks, sliding in grooves in the main case and connected to the stroke varving spindle. When the cylinder body C is revolved the floating ring F revolves with it, the resistance of the slippers being greater than that of the bear-



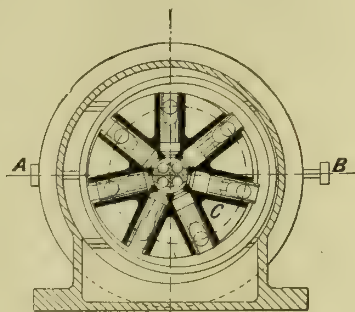
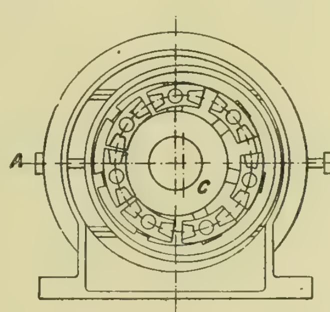


FIG. 4. FIG. 5.
SECTIONAL VIEWS OF HELE-SHAW PUMP.



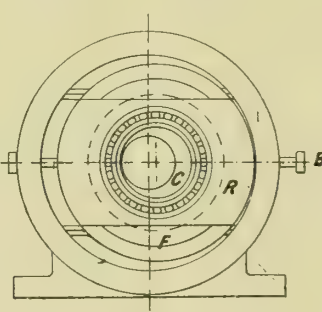
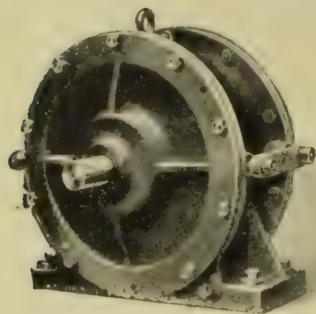


FIG. 6. FIG. 7.
DIAGRAMS SHOWING SLIPPERS AND INNER CASE OF HELE-SHAW PUMP.

ings R; in the central position the slippers make no movement in their grooves and in any other position only move to and fro to an extent directly proportional to the stroke. This of course effects a great saving of power, but beyond this it is evident that if the slippers moved round a groove in a fixed case, that the case would have to be retained full or partly full of oil to lubricate them sufficiently. The slippers and cylinder body would therefore churn up the oil and in doing so waste power. As F rotates with the cylinder body and slippers, it can be retained full of oil by centrifugal force and yet no churning takes place, the main case surrounding F being empty. The only place really subject to wear is where the cylinder body C runs on the central valve axle D, and this has been found after long periods of running to be practically inappreciable.



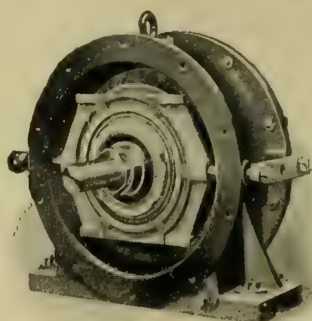
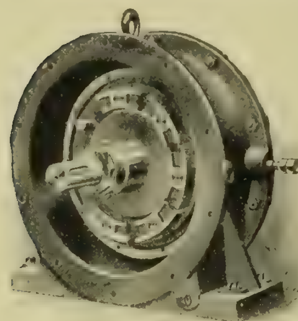


Fig. 8. Fig. 9.
Photographic Views Showing Exterior and Interior of Hele-Shaw Pump.



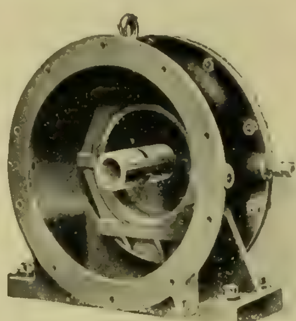


Fig. 10. Fig. 11.
Photographic Views Showing (Fig. 10) Interior of Floating Guide Ring and (Fig. 11) D Tube.

Fig. 8 is a complete external view of the pump, while Fig. 9 represents same with front cover removed. In this view one of the two roller bearings carrying the floating ring is seen, and also the guide frame on which this bearing is carried, and by which the floating ring is moved to and fro, and so the stroke of the pump made to vary. Fig. 10 represents the pump with half the floating ring removed, and the slipper blocks shown in position; two of these slipper blocks, however, have purposely been taken away in order to show exactly how the gudgeon pin is guided through a slot in the cylinder body. Fig. 11 shows both the cylinder body and floating guide ring removed, and exposes to view the central valve or "D" tube which is rigidly attached to the main body of the pump. The "D" tube, which acts both as the central valve and as the spindle on which the cylinder body revolves, has the valve ports cut in it and these are plainly seen.

Messrs. Charles Taylor (Birmingham), Ltd., of Bartholomew Street, Birmingham, exhibited a collection of machine tools and appliances of their manufacture, several of these being shown in operation. Prominently displayed were their well-known spiral chucks, each size and type being represented; and to demonstrate the superiority of material and design over the ordinary scroll chuck, the component parts of the spiral chuck were placed for inspection on a table. Both two, three, and four-jaw chucks were exhibited, the first-mentioned being suitable for brass workers. Some were fitted with false jaw blanks which could be bored out to grip any shape of casting, and others were fitted with hardened steel vee jaws for gripping bars and round castings.

The firm's patent machine vices were represented by several sizes of the standard pattern for use on the general run of work, as well as special deep jaw vices (a much stronger pattern for extra heavy work), swivel base, universal swivel base, and special wide jaw vices for light jobs. In addition, there were shown divided vices and loose vice dogs, for holding, on the machine table direct, work which is too large or awkward to be held in the vice itself.

Two of the exhibited machines shown we have pleasure in illustrating herewith, Fig. 12 being a patent plugging lathe, and Fig. 13 a rotary cutting-off machine for bars or tubes.

The plugging lathes have been designed for turning and finishing—at one chucking in most cases—taper plugs, in cast iron, gun-metal, or brass, for all sizes and types of cocks for gas, water, steam, &c., up to 2in. The work they will do includes turning shoulder, or collar, or in neck, and turning down and screwing or drilling and tapping the tail end, as required. The firm guarantee these machines to produce more perfect plugs more rapidly than any other on the market, and that by the use of unskilled labour. The lathe shown in operation on the stand was set up to produce medium-size plugs up to $1\frac{1}{2}$in., in cast iron or gun-metal, with the ends screwed or tapped. Although primarily designed for and described as being for cock plugs, their use is by no means

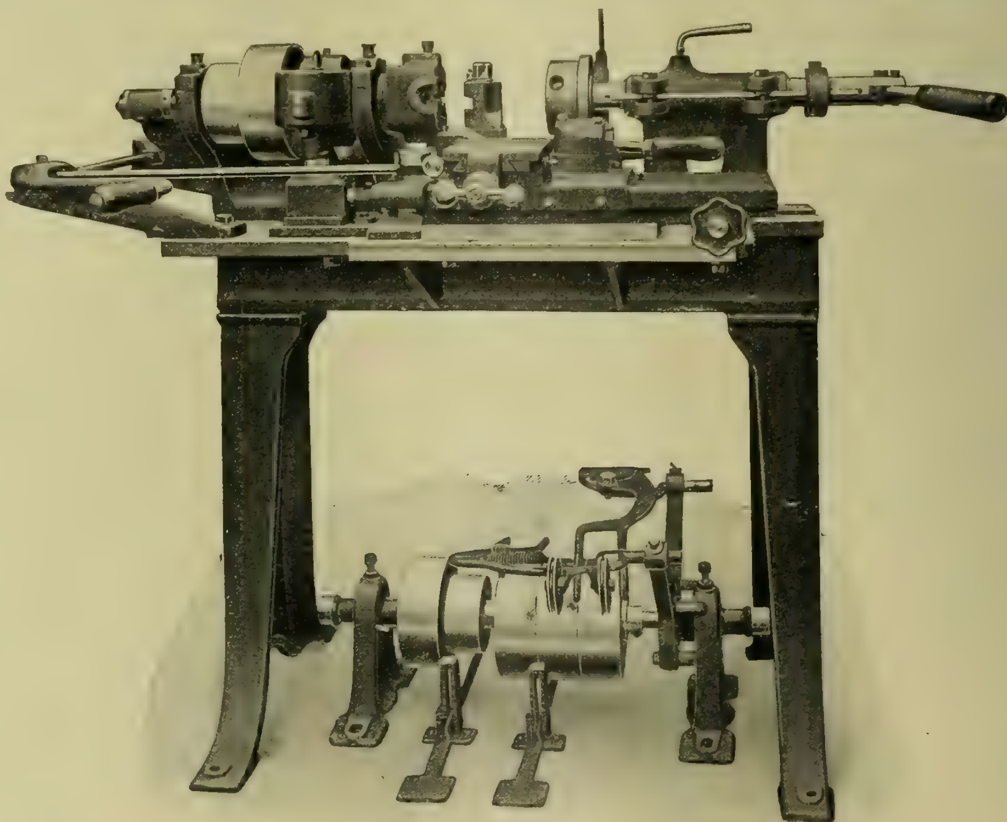


Fig. 12.—Plugging Lathe, shown by Messrs. Chas. Taylor (B'ham), Ltd., Birmingham.

confined to plug turning, as they are suitable for any small turning operations requiring self-acting traverse, either taper or parallel.

The rotary bar cutting machine has been designed for rapidly cutting off to length mild steel bars up to 3in. diam. or 2¼in. square, and as now perfected and placed on the market is claimed to be the fastest in existence for cutting off bars or tubes. The cutters revolve round the bar, which is held stationary in a vice, this plan obviating all the unpleasant features of revolving long and heavy bars, while it facilitates moving up and regripping the stock, as it is unnecessary to stop the cutters. This reduces to a minimum the time lost between cutting off several successive pieces, and the work being cut off perfectly square and flat is, in addition, much smoother than when sawn off by a circular saw. The machine will cut off 3in. round mild steel in 45 seconds, and 2in. gas tube in 18 seconds, this time including the moving and regripping of the bar and returning the cutters. Other diameters



FIG. 13.—ROTARY BAR CUTTING MACHINE. MESSRS. CHAS. TAYLOR (B'HAM), LTD., BIRMINGHAM.

and grades of steel bar and tube are dealt with in proportionately fast times. A two-speed countershaft, which can be operated while the work is in progress, is part of the equipment, and this permits an accelerated cutting speed when the cutters are approaching the centre of the work.

A substantial iron casting forms the main body of the machine and this is provided with split bearings, in which runs a hollow cast-iron spindle carrying the cutter head, which in turn is firmly attached to the spindle, and has two cutter slides operated by a hand lever. This lever feeds the cutters in by means of tension chains which pass through the spindle and have an automatic balancing device to ensure the cutters doing equal work. The spindle is driven by a balanced cast-iron pulley 16in. diam. for 3in. belt. The cutters are of plain oblong section, are rigidly supported throughout their length, and are so located as to have ample clearance at all points, and require grinding on one face only. Also by means of the balancing feature mentioned above, it is claimed that both cutters take an exactly equal cut even when carelessly set. The lower lever stop is fitted with a spring plunger, and this is set to act in such a manner that the spring is compressed as the stock is finally parted. This serves to retard the advance of the cutters at the last moment, and ensures that the end of the stock is left clean.

Other machines shown by Messrs. Chas. Taylor, Ltd., were capstan lathes, spinning, polishing, and brassfinishers' lathes, and double brass milling machine, but we have not space to describe these at length.

Messrs. The Mechanical Hammer Company, of Stalybridge, exhibited what was perhaps the novelty of the show in the

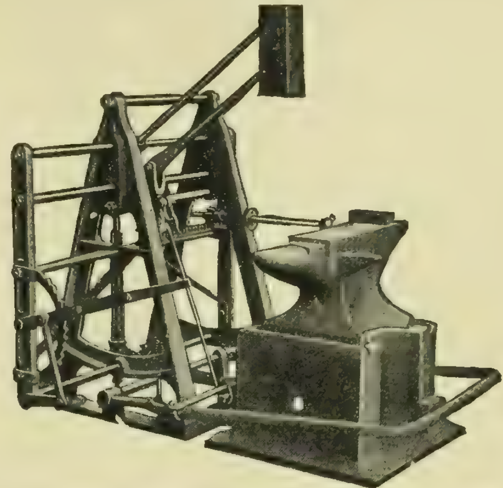


FIG. 14.—BLACKER'S PATENT HAMMER FOR FOOT POWER. MESSRS. THE MECHANICAL HAMMER COMPANY, STALYBRIDGE.

shape of a mechanical striking hammer intended to dispense with the services of a striker, especially in those smithies and workshops scattered over the country which are either too isolated to get any form of cheap power, or whose business is not sufficient to warrant the employment of a striker. Two forms of hammer were shown, one for foot power and the other mechanically driven, and these we illustrate in Figs. 14 and 15. The hammer-head swings radially, as will be seen, motion being imparted to it by means of the two parallel arms, by which also the head is always kept in a vertical position. This radial movement enables the hammer to be used for the piecing of hoops and suchlike things as cannot be got under the head of the ordinary vertical hammer. The principle of operation of both types is practically the same, and will readily be understood by a reference to the

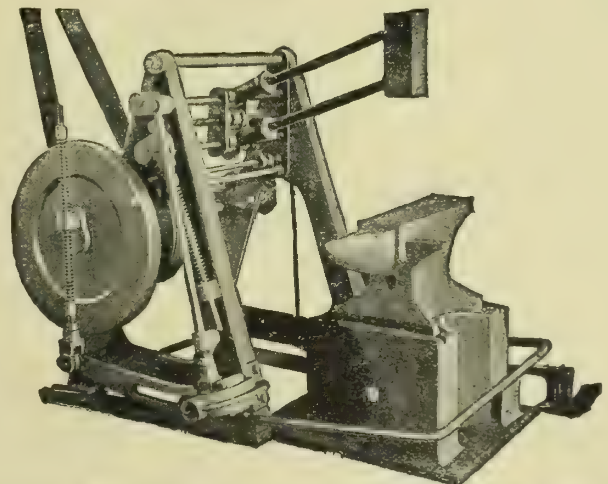


FIG. 15.—BLACKER'S PATENT HAMMER MECHANICALLY DRIVEN. MESSRS. THE MECHANICAL HAMMER COMPANY, STALYBRIDGE.

illustrations, and the following description, which applies to the power-driven machine.

As will be seen, there is a belt-driven shaft carrying a flywheel, on which is mounted a crank pin which passes through a block carried by a vertical rod. This block is cushioned on either side by means of two springs, as will be noticed in Fig. 15, and through them a reciprocating move-

ment is imparted to the vertical rod, which, in turn, gives a rocking motion to the curved slotted link, shown near the base of the left-hand upright of the machine. In this slot the bottom end of a second rod (which is attached to a crank giving movement to the hammer) slides, and it is obvious that the stroke of the hammer can thus be regulated by varying the position of the end of the rod in the slot. This is accomplished by depressing the footrail which runs around the anvil, and the operator can give either a heavy or a light blow, or a series of heavy or light blows, by the manipulation of this footrail.

At the other end of the shaft to where the power to work the hammer is taken off are a set of bevel wheels, and these are used for turning a lead screw, which in turn traverses the hammer backwards and forwards across the work as desired. The screw is brought into operation by means of the small rocking plate shown at the extreme right of the illustration, the depression of which to right or left at once takes the hammer to right or left as desired. This can also be regulated so as to knock off at any given point, so that the operator need not keep his foot on the plate, knowing that the hammer will come to rest at the required place.

THE PRODUCTION OF SMALL CASTINGS.

"METALLURGICAL Considerations in the Production of Small Castings" was the title of an address delivered by Mr. W. H. Hatfield before the members of the Sheffield Branch of the British Foundrymen's Association. Mr. Hatfield called attention to the use of the equilibrium diagram and phase rule in investigating the whole range of carbon alloys, and pointed out the importance of studying both steels and irons from this standpoint, as thereby a more complete co-ordination of the numerous facts now coming forward as a result of modern research was possible. He further demonstrated the necessity for an appreciation of physical chemistry prior to the consideration of metallurgical facts. He dealt with the production of small castings, of steel, cast iron, and more particularly of malleable cast iron. By means of lantern slides, microstructures of these materials were illustrated and described, and the influence of the various elements, such as phosphorus, silicon, &c., was shown. With regard to malleable cast irons, it was indicated that such material, properly produced, approximated in its mechanical properties to wrought iron. One of the lantern slides showed that the material clearly possessed the same ferritic structure, the only difference being that where in wrought iron a considerable quantity of slag was found under the microscope, in these samples of malleable cast iron a little free carbon was discerned.

Tungsten.—In a lecture on "Tungsten," delivered before the New York Electrical Society, Dr. C. Baskerville recounted the history of the metal from the time of its discovery by Scheele in 1781, when it was called tungstein. The metal occurred in nature as tungstates. The principal one was the iron salt known as wolframite. Calcium tungstate or scheelite, and lead tungstate or stolzite were also found in nature, but in smaller quantity than wolframite. Tungsten could be prepared from wolfram by heating the powdered ore with sodium carbonate, extracting the sodium carbonate with water, filtering and adding an acid to precipitate tungsten acid. This was washed and dried and the oxide thus obtained was then reduced to the metal by heating with carbon to a high temperature. Tungsten was also obtained by heating the oxide with carbon in an electric furnace, in which case the product was porous and could be welded like iron. Referring to the use of tungsten for electric lamps, the lecturer recounted the difficulties experienced in removing from the metal impurities such as sulphur, arsenic, antimony, and phosphor, which was very essential in order to obtain a sufficiently strong and uniform filament. Besides this, the carbon which was used in producing the tungsten must be removed, which caused considerable difficulty. The honour of the development of tungsten, he said, had wrongly been claimed by and given to Austria, when, in fact, it belonged to America. Credit should be given particularly to Dr. W. R. Whitney, of the General Electric Company, for bringing the tungsten filament to its present state.

OPEN-HEARTH FURNACE DESIGN AND MANIPULATION.*

BY JOHN PLOEHN.

THIS paper is confined to a description and the proportions, areas, and various main dimensions of the 25-ton basic open-hearth furnaces in operation in the steel foundry of the Bettendorf Axle Company, Davenport, Ia. The results obtained from these furnaces in time, quality, and life have been exceptional. The average time of 2,000 heats in the two furnaces has been 5½ hours on an average per heat of 22½ tons. The record of these furnaces is a 25-ton heat made in 4 hours 30 minutes, but all conditions were perfect to make this time. The charge was well balanced, the furnace comparatively new, and no trouble was experienced with the bottom or slag.

The average analysis of this same number of heats has been carbon 0·205 per cent., silicon 0·315 per cent., manganese 0·68 per cent., phosphorus 0·018 per cent., and sulphur 0·024 per cent. The life or number of heats made before shutting the furnaces down for repairs was as follows: Initial run of furnace No. 1, 403 heats; second run of this furnace is now over 609 heats, and the indications are that it is still good for at least 40 or 50 more heats. The initial run of furnace No. 2 was 573 heats, and the second run of this furnace was 401 heats.

These furnaces were designed for the use of either fuel oil or producer gas, but up to the present time they have been operated entirely on fuel oil. The chief feature of the design is the ample and generous proportions allowed in all portions of the furnace. The bath is both longer and wider, and from such little observation as the writer has been able to make, it is greater in these dimensions than is ordinarily found in this size furnace. When burning fuel oil a furnace should be much longer than when burning either natural or producer gas, but how much, is the question. In this case the furnaces are 10ft. longer than the average gas-burning furnace of the same capacity. On account of this extra length it is possible to obtain complete combustion before the centre of the furnace is reached, and thence on towards the other port the flame, having lost its cutting action and sharpness, very closely resembles a gas flame in appearance and action. For a 25-ton heat, the bath is neither shallow nor deep, but what would be called a medium depth, which seems to give better, quicker, and more uniform quality of metal than either a shallow or deep bath. The depth of bath for a 25-ton heat is approximately 16in. to 17in. The area of the hearth is 260 sq. ft., which allows a trifle more than 10 sq. ft. per ton.

The general outline and dimensions of the hearth are shown in Fig. 1. At the port ends it will be noted that there is no dog-house or monkey, these being omitted by using water-cooled oil burners. The area of the flues or up-takes leading to the slag pockets is 28 sq. ft. for each end of the furnace. The distance from the hearth bridge to the under-side of the roof is greater than the width of the ports, and the area at this point is 40 sq. ft. at each end of the furnace. Particularly when using oil, the construction of the ends of the furnace requires special care, as the flame is inclined to be extremely sharp and will cut out the ends of a furnace in a short time. This is almost entirely prevented by the extra length and the large areas at the points previously mentioned.

These furnaces were first designed with a hip roof and with the side walls contracted 12in. at the port ends. After the initial run of each furnace, both the side walls and roof were made straight. With the hip roof and contracted sides, both the roof at the hip, and particularly the side walls at the point of contraction, were cut away on the inside long before the adjoining parts of the roofs and walls were badly damaged. The expansion and contraction lengthwise are also better taken care of with straight walls and roof than with the hip roof and contracted ends. A small door is provided in each end of the furnace near the burner, approximately half-way between the top of the hearth bridge wall and the end of the hearth, and it has been found to be very useful for inspecting the end of the furnace, and also for

* Paper presented at the Buffalo meeting of the American Foundrymen's Association.

watching the action of the burners and the flame at this point.

The water-cooled burners, while requiring water for their operation, which in some localities would be quite an item of expense, have a great many advantages which more than offset the cost of the water required for their operation. The most important advantage is that the flame can be correctly located and positively kept in that location, because the burners are left in the furnace at all times. The burner tip, being water-cooled, is not liable to give trouble with the oil coking, which is the case with the plain burner. The general outline of the installation of these burners on the furnaces is shown in Fig. 2. The burners can be moved horizontally or vertically, and the tip of the burner can be elevated or depressed as may be required. The oil and air connections, being stationary, cause less trouble than on burners where they are pulled in and out at every reversal of the furnace. Fig. 2 also shows a further use of the water after leaving the burner. The water from the main is first led into the burner, and from the burner into a bulkhead through which the burner passes. From the bulkhead the water is led to a sewer. The use of this bulkhead is to support the burner, and also makes possible a smaller opening for the burner than through an arch brick opening, and, being a cooler wall, lasts much longer and makes it possible and more comfortable for the melter to look into the end of the furnace for the inspection of the roof and the flame. With water-cooled burners the furnace is reversed more uniformly and regularly, as it does not require the melter to climb over charging cars, &c., to pull out and shove in the burners, saving a walk of about 100ft. every 20 minutes, conserving his time and strength for better purposes.

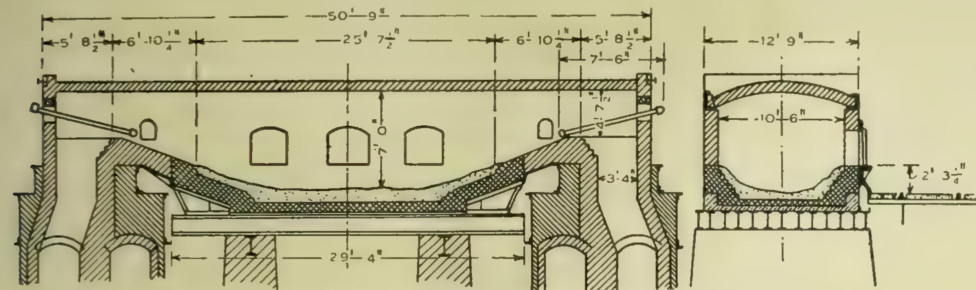


Fig. 1.—Longitudinal and Cross-sections of Open-hearth Furnace.

These furnaces have always been lighted at the slag pockets, which heats the checker brick quicker and is much easier on the new brickwork above, and does away with most of the preliminary heating in the hearth, also keeping all ashes and refuse out of the hearth. The doors and door frames are water-cooled, this feature not only protecting the door jambs, but also is appreciated by the melters, especially in summer. The door frames usually run from 400 to 600 heats, the centre frame usually failing first. When the water jackets on the doors are burned out they are relined solid with firebrick, and are used during the winter months. The use of coarsely-ground chrome ore has been found very valuable for patching door jambs and front and back walls at the slag line. It sinters easily on vertical surfaces, and makes a more permanent and lasting repair than magnesite.

Another advantage in having large areas at the end of the furnace is that the velocity of the outgoing gases is decreased so that the slag is not carried over into the slag pockets in any great masses, or in a molten condition. With ample areas, the top of the hearth bridge wall should also be at least 2ft. above the normal slag line, and in this design this dimension is very nearly 2ft. 6in.

A detail that is often overlooked is the intersection of the bridge hearth and port or flue. This is very often brought up to a square corner, which requires the outgoing gases to continue towards the end walls before going downward. To allow the gases to assume as near as possible their natural flow in turning downward, the intersection of the port and the hearth bridge should be on an angle of about 45°.

During the two runs of these two furnaces the slag in slag pockets has been in a granular or lumpy state, so that it was easily removed with pick and shovel without injury to the slag pocket walls, in two days after the shut-down. A false bottom of old steel plates covered with broken bricks and silica sand is placed 4in. above the floor of the slag pockets, this air space under the entire slag pocket serving to chill the slag and to keep the pockets cooler than if same had a solid floor. The area of the slag pockets is 90 sq. ft.

The slope of the checker bridge begins 1ft. inside of the slag pocket, and extends into the checker chambers a distance of 7ft. This easy slope allows free passage of the gases and prevents the retarding of gases due to too abrupt deflection against port ends or the checker chamber roof. The area of the opening above the checker bridge wall is 28 sq. ft. The checkers are directly in the rear of the slag pockets, and are of very large proportions, the actual volume being 120 cub. ft. per ton. In addition to this extraordinary volume, all the checker brick are of silica, and the results so far obtained prove that it is a good investment, taking into account the additional first cost of silica brick over firebrick.

After both the initial and second run of each furnace, the only repairs required for these checkers was a thorough cleaning, and from their present condition the checker brick will be good for at least another run of 500 heats, and then only the upper five or six courses will probably be replaced with new brick. The silica brick seem to have a greater capacity for storing, and are quicker to absorb heat than clay brick.

The area underneath the checker brick should be large so that the incoming and outgoing air and gases can distribute themselves uniformly through the various passages between the checker brick. The area of the flues under the checker brick in the air chamber is 12 sq. ft., and in the gas chamber is 8 sq. ft. The area of the flue leading from the checker chambers to the valve is 12 sq. ft., and this same area is maintained through the valve and in the flue leading from the valve to the stack.

For convenience in cleaning out the flues leading from the checkers to the valve when the furnace is down for repairs, a cast-iron rectangular manhole and cover is placed in the roof of the flue directly back of the centre of the checker chambers. This manhole saves considerable time when cleaning out these flues under the checker brick, and so far has not become warped or leaky. As the area of the flue leading to the reversing valve is practically the determining area, a summary is given below of the various areas mentioned, assuming this area as unity:—

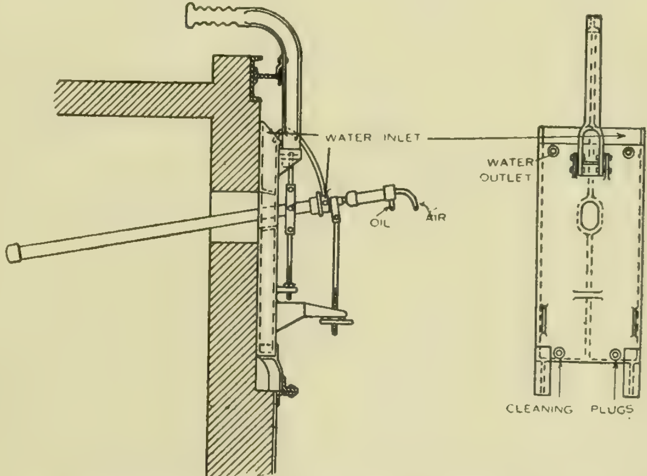


Fig. 2.—Water-cooled Fuel Oil Burners attached to Open-hearth Furnace.

Area under checker chambers	1·66
Area over checker bridge wall	2·3
Area in ports from slag pockets to port ends ...	2·3
Area over hearth bridge wall	3·3

To prevent water from accumulating in any of the flues or checker chambers, a drain is located in each flue and chamber, which is connected to a sewer discharging into a deep well, from which the water is pumped by an automatic

electric sump pump. A horizontal U-trap is placed below each drain, so that the air or gas cannot short-circuit, or pass from one chamber or flue to another.

With these furnaces were tried radial brick stacks, lined with firebrick their entire height. The height of stacks is 125ft., and the diameter inside at the bottom is 5ft. 9in., and at the top 4ft. 6in. These stacks have been in service for three years, and have as yet shown no cracks or weaknesses. The advantages gained are that they do not require painting every year, do not corrode, and are not affected by gases, and being a poorer conductor of heat, will maintain a higher temperature and subsequently better draught than a steel brick-lined stack of the same height.

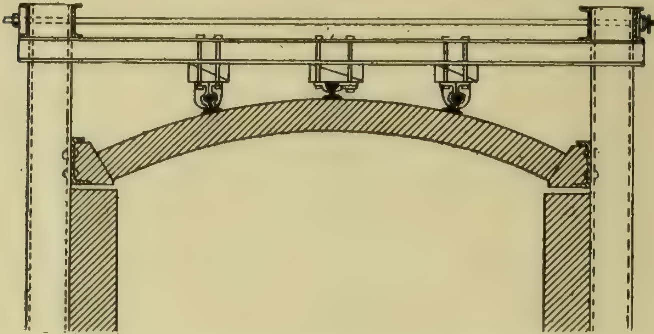


FIG. 3.—RIGGING FOR HOLDING THE ROOF OF AN OPEN-HEARTH FURNACE.

While drying out, and after the oil has been started, the roof of a furnace is a peculiar and particularly tricky structure. The life of a roof is practically determined by the treatment it gets, and its behaviour during the first 50 heats. To facilitate letting out the roof tie rods, both the nuts and tie rods are locked on the back or tapping side of the furnace so that all expansion and contraction can be taken up by loosening or tightening the nuts on the front side of the furnace, saving thereby considerable time, and allowing the amount of lengthening and shortening to be more accurately measured.

To prevent getting the roof out of shape in its earlier stages, a roof rigging was put on which is simple in its construction, and has been found to be very useful and effective in holding the true arch shape of the roof until the roof bricks are glazed enough to be practically one continuous mass. The rigging is shown in Fig. 3, and consists of three rails extending the entire length of the roof. The rails are suspended from cross-beams which are supported on the side buck-staves. Between the rail clamps and the cross-beams, wedges can be introduced to bring pressure on any particular rail when the weight of the rail alone is not sufficient. If necessary, the weight of the rail may be lifted entirely, making it independent of the roof if this should be found necessary. The cross-beams are not rigidly connected to the side buck-staves, and the expansion and contraction of the roof are taken up by the tie rods.

With this rigging, the bulging of a thin part of the roof can be controlled, and in most cases gradually brought back to the original true arch. An inspection of furnace No. 1, equipped with this rigging, shows that the roof still has its original true arch shape and that it has burned off uniformly on the inside, for which, of course, proper credit should be given to the melter for the careful handling of the furnace.

On these furnaces the skew-back channels are rigidly connected to the buck-staves so that the roof is entirely free from the side walls. A space is left below the skew-back channels so that the vertical expansion of the side walls can be taken care of. This keeps the roof practically straight throughout its length, and thereby makes it stronger and of longer life than if the skew-backs rested on the side walls and moved up and down or varied with the same.

A level-headed melter will appreciate and recognise the value of recording gauges and appliances that will show him the actual conditions of the elements that control his product, and they will be an incentive rather than an excuse for not getting a good product. When these furnaces were new, some heats were wild and over-oxidised, and after analysing all the conditions and charges, the trouble was finally located as being due to excessive draught under certain weather conditions. To regulate this, a recording draught gauge was installed, and this has proved to be a very valuable instrument. The damper can be regulated to give the same amount of draught for all conditions of weather and furnace, and the results have been accordingly more uniform. For this particular design of furnace and stack the draught that gave the best results was 0·8in. of water. Being recording, it gives a history of the day's run and permanent record for future comparison.

An air-controlled butterfly valve is used on these furnaces, and to give the operator warning that the valve is not entirely closed a small, inexpensive electrical device was installed. It consists of a contact point at the end of stroke, which, when the valve is closed, closes the circuit and lights a light on the platform. As the valves are usually under the platform and out of sight of the operator, it is hard to detect leaky valves, which, if allowed to continue, in time cause serious delay and trouble.

Another cause for oxidised metal was found to be due to the admission of too much air at the reversing valve. To give the operator the necessary information and to prevent guesswork, the screw stand on the platform was calibrated to show exactly the number of inches the doors are open. Since this was done, the doors are open only about one-half as much as before.

The practice of using too high air or steam pressures has been found to be injurious to quality. The pressures necessary vary for different furnaces and conditions. For these furnaces the air pressure during melting is about 60lbs., and during the time of working about 40lbs. The oil pressure is slightly higher or lower, depending on the kind of burner or atomiser used, and the distance necessary to pump the oil.

Various methods have been used to cover the steel plate of charging platforms, but none seems to give perfect satisfaction or is able to stand the heat or hard usage. As an experiment, a cinder concrete floor was laid on the steel plate, of a thickness which raised it to a level with the charging machine rails. This is shown in Fig. 4. To prevent corrosion of the steel plate in contact with the cinder concrete, a sheet of heavy tar paper was first laid on the steel plate. This floor has stood the hard service of three years' operation, and is in splendid condition at the present time.

This flush concrete floor has the advantage of being able to wheel across the tracks the materials used for the furnaces, furnishes the melter and helpers with a better and surer footing for rabbling out a puddle hole or when tapping heats, and is also cooler than a bare plate floor. Next to the furnace, removable cast plates in sections 4ft. long are laid even with the rails.

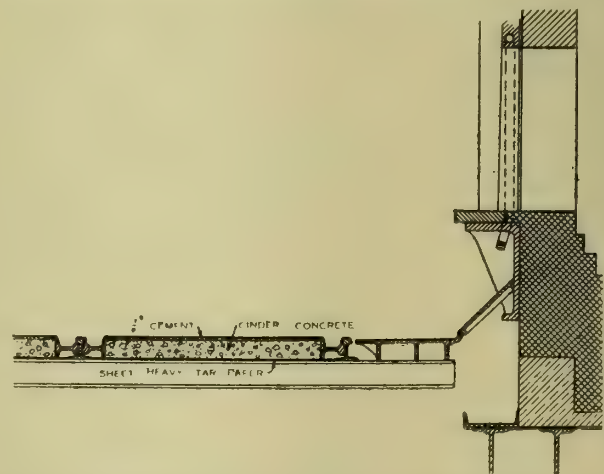


FIG. 4.—CROSS-SECTION OF CONCRETE FLOOR ON CHARGING PLATFORM.

Bins for storing the various materials used on the charging platform not only save a waste, but also make a safer and cleaner working floor. They are easily and cheaply built of a bottom plate, with sides, ends, and partitions riveted to it, leaving the entire side facing the furnace open for easy access for shovelling. The sides extend to a height to clear the charging machine, and the materials must be kept

below that level. It is surprising the amount of materials that can be placed in a small confined area. The several bins for one furnace are about as long as one-half the length of the furnace, but in them are kept sufficient materials for a week's run of fluor-spar, magnesite, burned lime, iron ore, dolomite, and chrome ore. The bins are placed on the concrete floor, but are not fastened in any way, so that they can be easily moved in case of furnace repairs.

Besides the draught gauge, both recording oil and air pressure gauges are used, and they have been found valuable to indicate an increase in pressure, especially of oil, which often creeps up gradually. It is true that the basic open-hearth furnace is a scavenger, and will make steel out of any kind of stock, yet to maintain uniform analysis, dead metal, and the high temperature necessary for the general steel castings, great care and judgment are necessary in the kind and proportions of the stock charged.

Thin and light scrap, especially when badly rusted, should be avoided, because not only is the percentage of loss higher in the furnace, but the large amount of oxide is hard on the basic lining, and very liable to produce an over-oxidised or wild metal. To arrive at the proper proportions necessary for different kinds of scrap, a series of test heats were made, in which the percentage of pig iron was varied from 50 per cent. to as low as 31 per cent., the various kinds of scrap making up the remainder of the charge. The percentage of different kinds of scrap was varied according to their carbon content. The pig iron was assumed at 3 per cent. carbon, and the carbon content of the scrap had to be sufficient, so that the calculated carbon of the charge was not lower than 1 per cent., with an average of 1·25 per cent. There was a total of approximately 50 heats in this test, and the time of heat, final analysis, and kind of metal of any one of these tests did not vary to any appreciable extent from the grand average of all heats. This proved conclusively that scrap of different carbon content should be kept in separate piles, and the following classification resulted: —

Scrap of carbon content up to 0·30 per cent. is kept in one pile or bin. In this class are structural shearings and short structural sections, couplers and knuckles and shop scrap.

Scrap of carbon content from 0·30 to 0·60 per cent. is the second class. In this class are old rails, &c.

The last class is scrap of carbon content above 0·60 per cent. In this class are springs, old rolls, &c.

At this plant, to be able to store an ample supply of charging materials under roof, not only for the advantage gained in the winter months, but also to be able to separate the various classes of scrap, large reinforced concrete bins were built in the furnace bay. The sides and ends of all these bins are 14ft. above the floor level, the bottom of the bins extending 4ft. below the floor to bed rock. Half of the bins are for pig iron, the iron from different concerns, or of off-analysis being kept separate. The unloading of cars and the loading of charging boxes is accomplished entirely by electric magnets, which makes possible the storage of materials in bins 14ft. high. To facilitate keeping these various kinds separate, it is necessary, when purchasing scrap, to specify that the various kinds be shipped in separate cars, and this can be done without additional cost.

If it is left to the yard or stock men to make up the charges, usually the scrap that is nearest at hand, or in their way, is sent to the furnaces, the consequence being that some heats melt high and some soft, introducing an unnecessary element of uncertainty in the time and quality of the product.

When it can be depended that the heats can be made in certain time, the cycle of smooth operation is reached, in that the time of charging and the work on the moulding and pouring floors can be arranged to better advantage.

Junior Institution of Engineers.— A meeting of this Institution will be held on Wednesday, the 11th inst., when the President, Sir A. Travor Dawson, R.N., M.Inst.C.E., will deliver his address, entitled "Staff Officers in Industrial Works: Their Scientific and Practical Training and Duties."

CONSTRUCTION OF ROTOR FOR STEAM TURBINES.

WITH the object of providing a rotor member for steam turbines in which the buckets are readily assembled, and in which the parts are connected together in a very rigid manner, Mr. W. J. A. London, chief engineer of the Terry Steam Turbine Company, Hartford, Conn., has recently designed and patented the construction shown in the accompanying sectional views, of which Fig. 1 is a side view of part of the rotor with one side plate removed, showing some of the buckets in central section and others in side elevation. Fig. 2 is a sectional view on the line R of Fig. 1, Fig. 3 is a sectional view on the line S of Fig. I, and Fig. 4 is a top view of one of the buckets. The rotor comprises a base ring A having a central circumferential groove B which is of dovetail form, as indicated in Fig. 2, buckets having tangs D adapted to fit in the groove B, spacing blocks E to space the buckets one from another, and side plates F circumferentially grooved on their opposing surfaces near their outer edges,

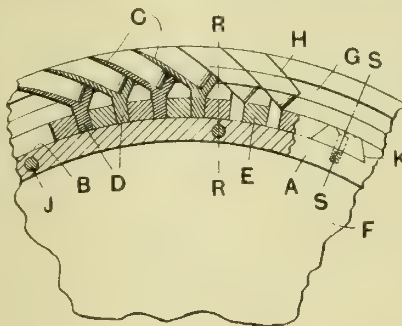


FIG. 1.

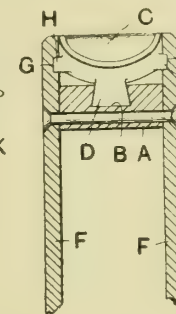
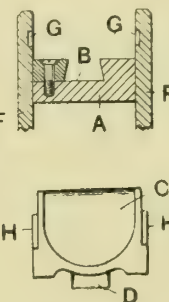


FIG. 2.



FIGS. 3 AND 4.

ROTOR FOR STEAM TURBINES.

as indicated at G, to receive the side ribs H on the buckets. Bolts or rivets J pass through the base ring and side plates, their ends being riveted over to tie the structure together. It will be noted that the buckets are arranged in step formation about the periphery of the rotor, and the structure is assembled by sliding the buckets into place on the base ring with their tangs in the groove, spacing them apart by the spacing blocks, then fitting the side plates so that the grooves G receive the ribs H, and finally in tying the structure together with the bolts J. There is thus provided a rotor which can be readily and accurately assembled, requiring little machining work and producing a strong, rigid structure. It is necessary to cut away the base ring in one or more places as indicated at K, to permit of the insertion of the tangs into the grooves when these parts take the dovetail shape.

Test Deflections in Reinforced Concrete.—At a meeting of the Society of Engineers held on December 2nd, Mr. Percy J. Waldram, F.S.I., M.C.I., read a paper on "Test Deflections in Reinforced Concrete," a subject which, he stated, was one requiring the closer attention of engineers before a standard of deflection was fixed by the proposed L.C.C. regulations; a standard which might or might not be correct or even safe. The stiffness of a beam was no criterion of its strength unless due regard were paid to the factors of depth and fibre stiffness. The small deflections of reinforced concrete beams were sometimes quoted as evidence of the strength of the material, but it was seldom noted that the deflections were small because the greatest loads placed on reinforced concrete were very much less than those commonly used upon wood or steel. Reinforced concrete was a much weaker material than steel or ordinary fir, for beams of equal size. A standard of deflection suggested by the author was referred to, but he pointed out that the effect of end fixing was not yet fully determined. The minute range of the deflections made it all the more necessary to use the greatest care in fixing a standard. Reference was made to the calculations necessary to determine the strength of reinforced concrete beams, and a number of formulæ were given, with explanatory notes. The application of these to well-known tests was shown by a series of eight diagrams, and particular attention was directed to one in which the conditions were such as were generally supposed to make the calculations almost impossible, on account of their intricacy. By the author's method, however, the problem was shown to be very much facilitated.

TRANSMISSION OF POWER BY BELTING.*

BY R. BERRY.

It is at times quite a problem to determine which is the most suitable belt for a particular job, without a proper knowledge of the surroundings. To my mind, the first thing is to ascertain the atmospheric conditions round about where the drive is intended to be. For instance, if in a very heavily saturated atmosphere, such as steam or damp, leather is positively useless, because it is well known that a few spots of water dropped on to the working face of a leather belt will cause instant slipping if the belt is working at anything like its full capacity. On the other hand, moisture on cotton, canvas, or even rope drives at times proves beneficial. For all moist atmospheres or outdoor work cotton, canvas, or rope is preferable; but in cases of warm, dry atmospheres (indoor work, of course) a good class of leather is far superior to either cotton, canvas, or rope. Canvas and cotton belts, if working in a very warm, dry shop, soon acquire a very glossy surface, while the pulley face becomes very nice and bright, which is a sure sign of slipping and loss of power. Leather, if properly cared for and treated with suitable dressing, may run for years with but little trouble.

Belting, like most things, has more than one side to be considered. In this particular case we have two important sides—the smooth or hair side and the soft or fleshy side. In England we are particularly fond of running our belts with the soft or fleshy side nearest the pulley face, but in America belts are frequently running with the smooth or hair side nearest the pulley. There is no doubt that the hair side has a greater coefficient of friction and consequently better pulley grip than the under or fleshy side, although the life of the belt will be somewhat shorter. Personally I favour the hair side being nearest the pulley face, not only for the better grip, but also improved efficiency. Again, it is a well-known fact that practically all the strength of leather is in the hair side. It is quite possible to cut 40 per cent. of the flesh side away without materially reducing the strength of the belt, thus showing that the soft portion only serves as a wad or pad which readily yields to the curved surface or pulley face, and not so much for strength. When designing a belt for the purpose of running with the hair side on the pulley face, care should be taken to avoid all large rivet heads. The most important properties that go to constitute an efficient belt are: Reasonable tensile strength, say 3,000lbs. per square inch; high adhesive qualities; practically free from elasticity; great flexibility; homogeneous throughout; not greatly affected hygroscopically.

Trouble is sometimes experienced by a belt constantly slipping, even though it has been tightened up to the very maximum tension the bearings and shafting will stand, without seriously heating up. In such a case there is only one legitimate way of getting over the difficulty, and that is to increase the velocity of belt by larger diameter of pulleys, or speeding up the shafting; by so doing better results will be obtained, with a reduced total tension upon the bearings and shafting, which will have a double effect of curing the slipping and minimising the chance of bearing and shafting seriously heating up.

The average tensile strength of ordinary leather belting is 3,000lbs. per square inch, that of rope being about 20 per cent. higher, although I do not attach much importance to this knowledge because I consider the breaking strain of any belt material ought to be quite a secondary consideration, seeing that the working tension is always a small fraction of the breaking strain, usually about one-eighth. A belt of high tensile strength, but with a correspondingly low coefficient of friction, although very strong, will be a very poor transmitter of energy.

Of late we have heard a great deal about the successful employment of steel belts running on rubber or cork-faced pulleys. Prof. Kammerer, of Berlin, makes great claim for these, and shows some remarkably good results obtained from steel banding. Personally I fail to see any great advantage in the employment of such high tensile material, and cannot help but feel that the consequences might be very serious if a long steel belt, very much like a bandsaw, only considerably wider, longer, and heavier, should break. While a good class of steel may have a tensile strength 20 times greater than ordinary leather, and a steel belt 1in. wide do the work of a single leather belt 20in. wide, I cannot, even on this assumption, see any real advantage. In the first place, if one material is 20 times stronger than another then we increase our working tension by the same ratio; obviously the factor of safety is practically the same, and pressure per square inch of surface made by the steel belt on rubber-faced pulley must be enormous, and one that would soon, I should imagine, cut a deep furrow in the composition.

Again, a steel band running upon a rubber-faced pulley cannot possess a better coefficient of friction than a rubber or cork-faced belt running upon an iron-faced pulley, so that everything carefully considered from my point of view, the only real advantage obtained by the use of steel belting is that the space occupied is very much narrower, as well as the pulley faces. Also in other parts he shows belts travelling at a velocity of 10,000ft. per minute, and judging from what I know of pulleys, however carefully balanced, that is a dangerous speed, and not to be recommended.

It is usual to assume that the number of revolutions of two shafts connected by a band is inversely as the diameters of both driver and driven pulleys, and for most purposes it is perhaps safe to accept it as such, although, strictly speaking, it is not quite true, because when a belt is doing work the tight or working side will be constantly stretching considerably more than the slack side, the amount depending upon the elastic properties of the material used in making the belt and the working tension or load brought upon it. Consequently the pulley and shaft which are being driven will fall behind in speed by an amount equal to the excess of extension. For instance, it has been shown that by using a very elastic belt the driven shaft was only running about half-speed of the driving shaft, although both pulleys were practically the same diameter. The creeping effect which is constantly going on will also tend to increase this lagging behind of the driven shaft, which is also increased by the longer distance between shafts, although there may not be any slipping (in the real sense of the word) going on. The creeping effect of belts is often spoken of as being a legitimate effect of lagging behind, which is an actual loss of power, and one that unfortunately cannot be avoided, either by means of belt tighteners, belt compounds or solutions, or patent pulley coverings. It is due to the band undergoing compression and tension every time it passes over the pulleys, and cannot be prevented by tightening up the belt; therefore it does not represent the usual slip often experienced when running with slack belts. With a good class of material the amount of creep should not exceed 1 per cent., whilst the amount of slip due to unequal stretching between tight and slack sides of belt should not exceed $1\frac{1}{2}$ per cent. Therefore the total lagging effects upon a properly designed belt drive should not be more than 2 to $2\frac{1}{2}$ per cent.

In selecting a suitable leather belt to perform a certain duty care should be taken to avoid double leather belts as much as possible, especially where the pulleys are very small in diameter. If a belt gives trouble by constantly slipping, better by far increase the velocity of the belt by increasing the diameter of both pulleys if possible, for by doubling the velocity of the belt a double output in energy transmitted will be obtained without the slightest increase of pressure upon the bearings, pulleys, and shafting. Thus the life of the bearings, shafting, and loose pulleys are prolonged, and the total frictional losses are considerably reduced or the combined overall efficiency improved. The weight of a belt should be as small as possible, consistent with the extreme power to be transmitted by it; this not only saves a waste of power in keeping the belt itself in motion, but its lightness also reduces the centrifugal action that tends to keep the belt from coming into proper contact with the pulley face, especially at very high speeds. Anyone who has noticed a double leather belt passing round a small pulley at very high speed must have observed the belting being pulled away from the pulley face several degrees, due to the rigidity and inflexibility of the belt, and if the arc of contact is as important as we are led to believe, then I am perfectly in order in trying to, as much as possible, discourage the use of double leather or any other heavy, thick belt material.

* Abstract of paper read before the Birmingham Association of Mechanical Engineers, November 21st, 1912.

In making this statement I am fully aware of the fact that it is not always possible, or even convenient, to obtain a high velocity of belt speed without going to the great expense of practically re-designing the machine, and often machine-makers put pulleys far too narrow and too small in diameter to allow of a suitable belt being fitted. In such cases as these there is no alternative but to put on a double leather belt, or even compound it by putting on a second belt the same width, to ride upon the top of the original one. In either case an excessive tension is put upon the shafts and bearings. If both pulleys are reasonably large in diameter, say not less than 4ft. or 5ft., there is not much harm in using double leather belting.

Engineers are generally agreed that for the purpose of causing a belt to always run in centre of pulley it is necessary to have the pulley faces rounded, but to what extent all do not agree. Therefore it is no uncommon thing to see a band running upon two pulleys with a wide difference of convexity or roundness of face. In fact, one can see at times a band running from one pulley (probably the driving pulley) with a very much rounded face to another having a perfectly flat face, which, to say the least, cannot be considered good practice, and must be very injurious to the band. The diameter of a pulley should not have any influence with regard to amount of convexity, this being solely controlled by the width of face, and in order to adopt some universal method the writer suggests the following: Square the width of face measured in inches, and add 10 to the result, the figure obtained being used as the radius for striking the arc of convexity, from which sheet-steel gauges could be struck, made, and kept by for use. As an example, take a pulley with a 6in. face, then $6 \times 6 + 10 = 46$. This should be the radius for striking the arc. This is a method I have used for many years, and it has proved very satisfactory for any width of pulley. It will also be found thoroughly consistent with good practice, and if generally adopted would entirely remove the unsightliness of such varied degrees of convexity.

With regard to the arc of contact there appears to be a tremendous lot of misapprehension. Text-books dealing with power transmission invariably refer to the importance of the arc of contact, and also refer to the great gain for a slight increase in the arc embraced by the belt. Usually this increase is produced by jockey pulleys or idlers, and by endeavouring to get the slack side of belt on top. There is no doubt that as you increase the arc of contact, embraced by real direct tension, you must obviously increase the gripping powers of the belt, but to increase the arc of contact by idlers, jockey pulleys, or having slack side of belt on top, I consider to be a very poor way of obtaining the object; to my mind it is robbing Peter to pay Paul. Neither does it speak any too well for the designer. It has always been a mystery to me why engineers should put down slow revolving engines or main shafting to drive high-speed machines, then, owing to the great ratio between two pulleys, resort to idlers or jockey pulleys, placing them near the smallest pulley for the purpose of increasing the arc of contact. If the machines to be driven are of necessity high speed, by all means speed up the driving shaft or put down high-speed engines, gas, oil, steam, or even steam turbines, and either couple up direct, or if it must be belt drive, then design same to have pulleys of equal diameter or thereabouts, but certainly not more than 4 to 1 ratio.

With regard to distance between centres of shaft, I have always considered the case to be well met if we take total circumference of both pulleys to represent distance between centres of shaft, whatever the diameter of pulleys may be. Such distances, to my mind, give sufficient flexibility and room to turn in without useless waste of belt material.

After a new machine (either electrical or mechanical) has been fixed and the belt attendant summoned to measure for the necessary length and width required, one of the greatest difficulties he has usually to contend with is how to determine the proper width it should be in order to just transmit sufficient energy to obtain the maximum rated output from new machine, with a minimum initial tension on both shafting and bearings and consistent with highest efficiency.

The length is quite easy to measure, but width and thickness is quite another matter altogether, so that, generally speaking, the only guide the non-technical man has to help him in deciding this is the width across the face of the pulley or band guide, which is usually supplied with machine. Then if by some mistake or other the pulley supplied with machine is rather wider than actually necessary, then the purchaser or employer of belt man will be put to the extra expense of buying an unnecessarily wide band, owing to the man's inadequate knowledge of belt tensions or of belt capacity generally. On the other hand, should the pulley be too narrow or too small in diameter for the full or rated amount of work the machine is guaranteed to perform, then the man whose duty it is to attend to the banding will be continually called upon to either use some band solution or tighten up the band every time the machine is being worked up to its rated output.

To be continually tightening up the belt means courting mishaps and further trouble, because there is a limit to the tension which belting will stand, and having reached that limit, the band ultimately breaks and so causes a complete stoppage, which may be rather serious. There is also another point to be considered with running belts which have been tightened to an excessive pitch, and that is the life of bearings, shafting, and loose pulleys. It stands to reason that where very excessive tensions are employed the life of all wearing parts must be considerably shortened. This causes great loss of time, money, and temper, and is altogether very unsatisfactory.

After years of experience with belt drives and engineering generally, the writer has found that a good all-round and easily-remembered rule for belt calculations is that 1ft. per minute of belt speed per inch width of belt is safely equal to transmitting one watt of electrical energy. So that if we multiply the band speed in feet per minute by the width in inches the result will be total energy in watts, or (dividing by 1,000) equal kilowatts that the band can safely be relied upon to transmit, without any undue tension being brought upon any part of the band, or excessive friction on any part of the machinery. It must be strictly understood that these data only apply to single leather belting or woven belt of equal thickness. If a light double leather band be employed, then 25 per cent. more energy may be calculated upon, or for heavy double leather as much as 60 per cent. more may be added.

The great advantage in adopting this method or rule is that it fixes a constant for working tensions, so that the working tension becomes directly proportioned to the width in inches, this constant being 44·24lbs. pull per inch width of belt. Therefore, if it is required to know the difference in pounds pull on the tight and slack side of any belt, all we have to do is divide the total output of machine measured in watts by velocity of belt in feet per minute and multiply results by 44·24, and the product will be the extra pull in pounds of the tight side over the slack. It also conveys some idea to the average man, when he is deciding upon a belt, as to what amount of stress is likely to be brought upon the belt when being worked up to the maximum load, thus obviating all troubles arising from belts being either worked excessively tight or ridiculously slack. The above working tension per inch width of belt is fairly low, being one that any class of belt should stand.

Taking our rule, which teaches us that 1ft. per minute of belt speed per 1in. width of belt is equal to transmitting one watt of electrical energy, we find that to divide the total output (of any dynamo or motor) given in watts by the velocity of belt measured in feet per minute, the result will give the width of belt required for that dynamo or motor.

Then, formulating the rule, let W equal width of belt in inches, T equal driving tension per inch width of belt, V equal velocity of belt in feet per minute, F equal total driving tension of belt. Then we have:—

(1) $W \times V$ = output of machine in watts.

(2) $\frac{W \times V}{746}$ = E.H.P. (electrical horse-power.)

(3) $\frac{\text{Amps} \times \text{Volts}}{V} = \frac{\text{Watts}}{V}$ = width of belt required = W in inches.

(4) $\frac{\text{H.P.} \times 746}{V} = \frac{\text{Watts}}{V}$ = width of belt = W.

(5) $\frac{\text{H.P.} \times 746}{W} = \frac{\text{Watts}}{W}$ = velocity of belt = V.

(6) $\frac{\text{H.P.} \times 33{,}000}{W \times V}$ = driving tension per inch width of belt T.

(7) $W \times T$ = driving tension (F)

Velocity in feet per minute.	Centrifugal force in lbs. per one inch in width by—			
	¼in. thick.	⅜in. thick.	½in. thick.	1in. thick.
feet.	lbs.	lbs.	lbs.	lbs.
500	·23	·35	46	·93
1000	·93	1·4	1·86	3·73
1500	2·09	3·15	4·2	8·4
2000	3·72	5·6	6·24	14·92
2500	5·7	8·6	11·5	23·
3000	8·37	12·6	16·87	33·57
3500	11·4	17·	22·7	45·4
4000	14·62	22·4	29·24	58·49
4500	18·81	28·35	37·8	75·6
5000	22·8	34·4	46·	92·
5500	28·1	42·1	56·2	112·3
6000	33·4	50·	66·7	133·4
6500	38·3	57·5	76·6	153·2
7000	45·6	68·	90·8	181·6
7500	52·2	75·2	104·4	208·7
8000	58·48	88·5	116·96	236·
8500	67·3	100·54	134·6	268·13
9000	75·	112·5	150·	300·

To calculate the stress on banding in motion due to the action of centrifugal force.

Let W equal the weight of 1 cub. in. of leather which equals, say, ·0358lbs., and

$$\text{Centrifugal Force} = \frac{\cdot 0358 \times V^2 \times 2 \times R \times 12}{G \times R \times 2} = \frac{\cdot 4296 \times V^2}{G}$$

So that a single leather band running at 6,000ft. per minute, and ¼in. thick, will have a stress of 33·4lbs. per inch in width.

It should be noted that at 6,600ft. per minute the stress of centrifugal force is just equal to the maximum driving force, whatever the width may be, consequently the factor of safety is very considerably reduced at this excessive belt velocity.

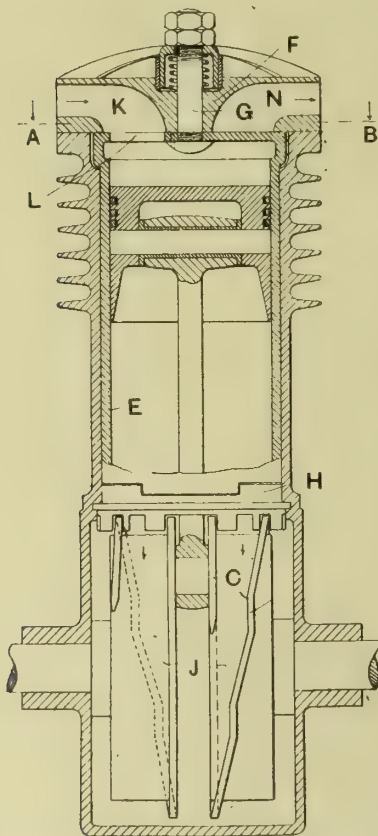


FIG. 1.—INTERNAL-COMBUSTION ENGINE WITH ROTARY VALVE.

INTERNAL-COMBUSTION ENGINE WITH ROTARY VALVE.

THE accompanying illustrations show a design of internal-combustion engine, the joint invention of Mr. T. Spencer James, Buffalo Works, Strand-on-Green, Chiswick, Mr. R. Gordon Orr, and Mr. G. J. Maude. The engine is of the type in which the piston reciprocates within a rotary liner arranged within the cylinder and adapted to effect communication between its interior and the inlet and exhaust ports at the desired times, the necessary rotary motion being imparted to the liner by co-operative gearing at the base of the liner and on the crank shaft respectively. Fig. 1 shows a sectional elevation of the engine, Fig. 2 a plan view of the top of the rotating liner, and Fig. 3 a cross-section on line A—B of Fig. 1.

The cylinder, crank case, piston, piston rod, and shaft are of the usual design. Within the cylinder a rotatable liner E is fitted, and is supported in place at its upper end by the head F of the cylinder by means of a bolt G passed through both the end of the liner and the head, the flat contacting surfaces of both being gas-tight. The liner is free to rotate with the bolt G, and is turned by a notched ring H rotatably supported between the crank case and the cylinder. The rotation of the ring is transferred to the liner

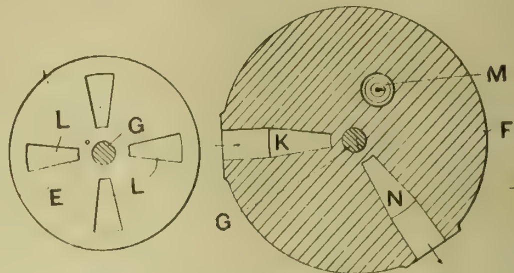


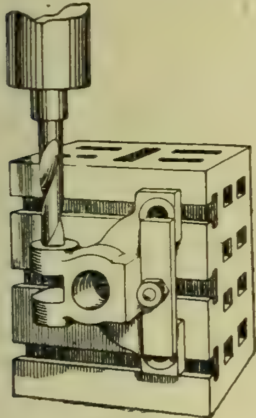
FIG. 2. FIG. 3.
INTERNAL-COMBUSTION ENGINE WITH ROTARY VALVE.

by the projections in the end of the liner fitting within recesses or notches on the ring. The under side of the ring H is cut to receive a worm or helix C, the convolutions of which are interrupted by straight portions. The worm is provided on the crank cheeks J, the arrangement of the cuts and the worm being such that the liner is turned to bring one of the openings L opposite the intake K when the piston descends, to close all the openings when it ascends, to bring an opening opposite the sparking plug M, and when the piston has again descended or thereabouts and is re-ascending, to bring an opening opposite the exhaust N, the sequence being repeated for the charging, compressing, firing, and scavenging of the cylinder. The crank is out of line with the centre of the cylinder for the purpose of allowing the interrupted worm or helix to gear with the front and clear the rear portion of the notched ring. The interrupted worm is of irregular curvature for the purpose of producing the required intermittent movement of the liner, and hold it stationary when compression and firing take place, and also during part of charging and exhausting. The liner bolt G is made fast to and carried round by the liner and the cap and sheath is in turn, by a feather or key, carried round by the bolt also; a spring, as shown, is compressed by means of the nut, thus holding up to the cylinder head or buttressing the spring-suspended liner, the cap preventing the friction of the piston on the suction stroke from actually severing the gas-tight joint set up.

Black Line Reproductions of Tracings.—A method of making black line reproductions of tracings was described by Mr. C. F. Bell before the New York Society of Municipal Engineers as follows: A blueprint is made, using a very slow paper, the chemical coating on which is slightly different from that in general use. This print is not washed, but is placed face downward on a sensitised gelatine plate and an ordinary gum roller is run over it. The paper is then removed, having in this short time etched a negative on the gelatine. If any dirty spots appear on the plate they are removed by a wet sponge. This plate is then inked with a special printer's ink from a gum roller, only the etched portions taking the ink. A print is obtained by placing the paper or cloth over the plate and running a roller over it. To make duplicate prints, no further work is necessary than to re-ink for each impression. There is no distortion, and while a Van Dyke print shows brown lines on a somewhat discoloured background, the black print above described can be made on any material, and gives good black lines on a clean background, which allows the making of additions in ink without changing the general appearance of the print. In the Van Dyke process the lines of the print are in the paper itself, while the lines of the black print are printed on the surface of the paper and can be removed with an eraser. A field office may at different times need blueprints of a tracing that is in the general office and for that purpose a black line print on a thin strong paper, which is an exact duplicate of the original tracing, and from which blueprints can be obtained, can be sent to and kept on file at the field office.

SOME USEFUL MACHINE TOOL ACCESSORIES.

We have pleasure in illustrating herewith several ingenious machine tool accessories, &c., manufactured by Messrs. Edward G. Herbert, Ltd., of Atlas Works, Levenshulme, Manchester, which we were unable at the time to include in our notice of the firm's exhibit at Olympia. They will be found almost indispensable adjuncts to planing, shaping, and drilling machines, and as such we anticipate that the firm will have a large sale for them.



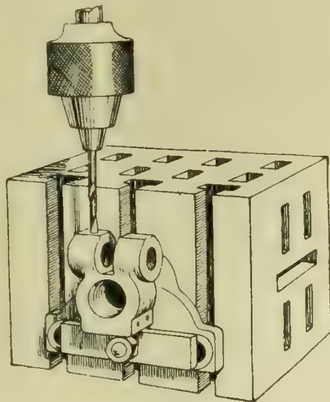


Fig. 1. Fig. 2.
Box Jigs. Messrs. Edward G. Herbert, Ltd., Manchester.

Figs. 1 and 2 show a convenient form of box jig, the use of which renders it possible to machine or drill on five different sides of an object at one setting. The work, as will be seen, is fixed on the most convenient side of the jig, which can then be turned on to five different sides in succession, or carried from machine to machine without resetting the work. Besides saving a number of settings, this ensures that all the holes and surfaces are square or parallel to each other.

Figs. 3 and 4 show an adjustable angle plate by the use of which work may be quickly and correctly set at any angle, with a great saving of time over old methods. The plates are set by loosening two nuts and turning the plate round till the indicating line is opposite the required angle on the scale of degrees. The nuts are then tightened up and the plate is ready for use.

Fig. 4 shows how they may be used with the "Rapid" machine vice, another of the firm's specialities. This vice is so constructed that when the bolt is slackened the loose jaw is quite free to slide, and can be instantly adjusted to any size of work. It can also be swivelled, or entirely reversed, so as to convert the vice into a dog, and in this way two vices can be used to hold work up to any size. The action of the bolt is to draw the jaw downward, and this gives the work a true bed, whereas in the ordinary type of screw vice the jaw tends to spring upwards and so lifts the work.

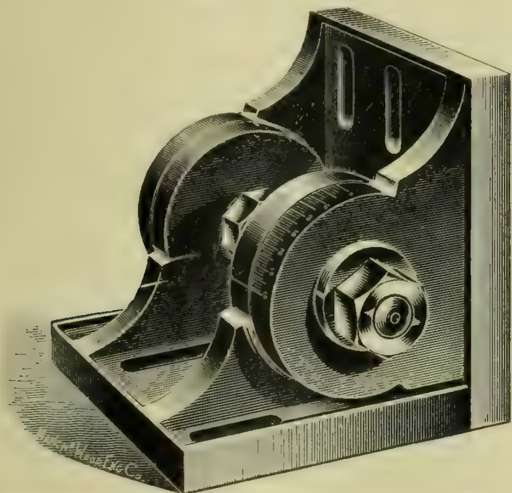


Fig. 3.—Adjustable Angle Plate. Messrs. Edward G. Herbert, Ltd., Manchester.

Figs. 5, 6, and 7 show an adjustable chain bolt, some of the uses of which will be understood by a reference to these illustrations, though, of course, innumerable others will suggest themselves to the reader. The chief advantages claimed for this type of bolt is that the length can be instantly altered; one adjustable bolt takes the place of a whole set of ordinary bolts; they can be passed round objects such as pipes, cylinders, &c. (see Fig. 6); they save the time usually spent in looking for special length bolts; and avoid the necessity of bending bolts (see Fig. 7.) All parts are strictly interchangeable, and extra chain can be quickly added by inserting a pin, as will be readily understood.

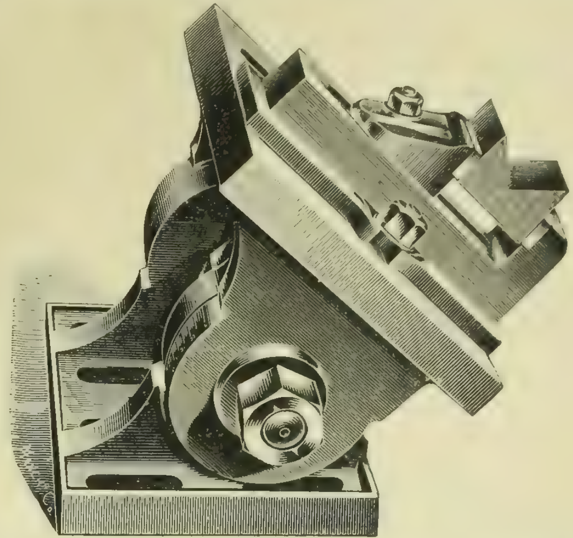


Fig. 4.—Adjustable Angle Plate. Messrs. Edward G. Herbert, Ltd., Manchester.

Figs. 8 and 9 show a "Combination" cramp made by the firm, and the many uses to which this can be put will make it indispensable in the machine shop. It consists of a strong steel arm, hardened on its wearing surfaces, and pivoted on a cast-iron block. Used as an end cramp (Fig. 8) in cases where the work has to be machined on the upper surface, it holds the work firmly and presses it down on the surface of the table, thus ensuring a perfectly true bed. The two bolts in the block enable it to take the thrust of the tool without shifting, the larger sizes being suitable for the heaviest class of work.

Used as a side cramp, it holds the work firmly and presses it down in the same way as when used as an end cramp. Only one bolt is required to fix the block down, and this can be placed in either of the two holes shown in Fig. 8. One of these will probably suit the machine table slots, but by turning the block round two further positions are secured, as the pivot is nearer one hole than the other.

Used as an ordinary cramp (Fig. 9), as the arm is pivoted out of the centre of the packing block in both directions, turning the block round gives a different gripping height for each of the four sides of the block. No time is thus wasted in looking for the usual packing blocks.



Fig. 5.—Adjustable Chain Bolt. Messrs. Edward G. Herbert, Ltd., Manchester.

Figs. 10 and 11 show a key extractor, a new tool for the use of millwrights and general engineers. This device enables keys to be easily withdrawn from pulleys, rolls, heavy gearing, &c. In use two small grooves are cut in the key with a chisel or file, as shown at A in Fig. 11. The jaws of the extractor fit in these grooves, and the screws B, B prevent them opening. The frame of the extractor abuts against the boss of the wheel or pulley D, and the key is easily withdrawn by turning the nut C. It will be seen that the use of this device effects a great saving of time and labour, and also avoids damaging the keys or pulleys.

THE INDIVIDUAL ELECTRIC DRIVE IN WEAVING SHEDS.

A PAPER on individual electric drive in a modern weaving shed was read by Mr. S. N. C. K. Whitehead at a meeting of the Manchester Students' Section of the Institution of Electrical Engineers, in the Municipal School of Technology last week.

A factory, he said, was understood to be equipped with individual electric drive when every machine in it was driven by a separate electric motor, and it was only within recent

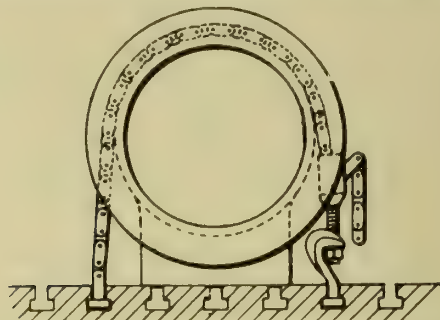


FIG. 6.—ADJUSTABLE CHAIN BOLT USED ON ROUND OBJECT. (See p. 713.)

years that this method of driving weaving sheds had come to the front, owing to the conservatism of British weavers, who had been suspicious of adopting any system so radically different from what they had been accustomed to. But the general advantages of this individual drive were so marked that now when new sheds were erected the owner nearly always considered the individual electric drive as an alternative to electric group or mechanical drive.

Discussing first the choice of electrical supply, Mr. Whitehead pointed out that direct current was quite out of the question for the purposes under consideration, because it was of vital importance that the turning movement of the mechanism driving the loom should be absolutely steady and free from any impulses or shocks, however slight. It was also necessary that the starting of the looms should be rapid and without jerk. The loom should be running at its full load speed almost directly it was started. This condition might be satisfied by a direct-current series motor thrown directly upon the supply mains, with perhaps a small permanent resistance in series, but it would be very inefficient, as losses would occur in the resistance. If this resistance were cut out when the motor was up to speed a jerk might result which would ruin the fabric. In starting directly, again, there was always the danger of a small motor "bucking over." Experience proved that a great saving was effected by using the polyphase high-efficiency loom motor, and, in his opinion, the most suitable scheme for a weaving shed was a 3-phase 50 or 40-period, 200 to 230-volt system.

In securing current, there were advantages in purchasing

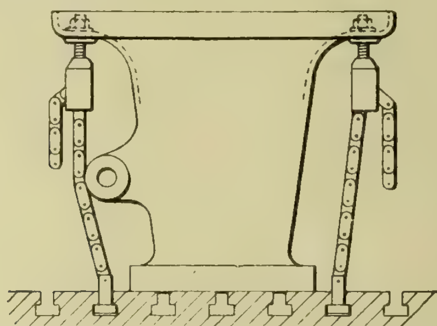


FIG. 7.—ADJUSTABLE CHAIN BOLT, TAKING THE PLACE OF A BENT BOLT. (See p. 713.)

from some public supply company if there were one within reasonable reach. It meant less initial capital expenditure and greater economy of space. After describing the desirable qualities and the mechanical and electrical characteristics of the electrical gear likely to be met with in weaving sheds, Mr. Whitehead compared it with other apparatus used there for the same purpose.

The advantages of individual electric drive, he said, were many. For the most economical operation it allowed of the selection of exactly the right power unit for every machine to be driven. The absence of belt and shafting—an especial advantage in the eyes of continental experts—greatly increased the light in the sheds and made them much cleaner. Belts flung dust about and dropped oil on to the cloth. Then additional looms might be added with the greatest ease. Should the owner of the belt-driven shed have in mind future extensions, he would have to provide abnormally large shafts to take into account the extra expected load; whilst the owner of the electrically-driven shed had only to see that his generating plant would take care of the extra load put upon it, or, when taking power from a public supply

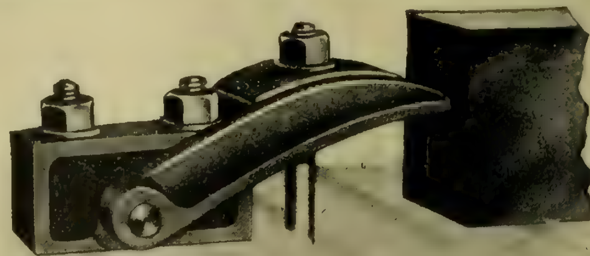


FIG. 8.—"COMBINATION" CRAMP USED AS AN END CRAMP. MESSRS. EDWARD G. HERBERT, LTD., MANCHESTER. (See p. 713.)

company, to see that his main wiring would stand the extra load. Due to constant rotating speed, a better quality and a larger quantity of fabric was produced. In a belt-driven shed, with a group of looms running off the same shaft, should some looms be shut off the speed of the others would increase, and conversely, so that the productive power of the loom would be continually altering. With individual electric drive the shutting down of one machine would not affect in the slightest the speed of the others, so that the looms would always be running at their theoretical maximum speed. To allow for occasional variations a belt-driven loom had to run at an average speed, and consequently the output was less.

Practice had shown that where there were numerous belts and countershafts to be driven there was a great friction loss in the shafts, thus greatly increasing the cost of production. In an electrically-driven shed there were losses in transmission, but only to a very small extent, and they remained constant, whereas the friction losses increased as the shed grew older. Further, when a loom was not in use its motor could be completely switched off, and then absorbed no power. With the mechanically-driven loom this was not so, for supposing 15 looms were driven from one countershaft, and 10 were shut down, the losses due to friction in the line shafting and belting were still being maintained. The power consumption of each loom could be measured by inserting

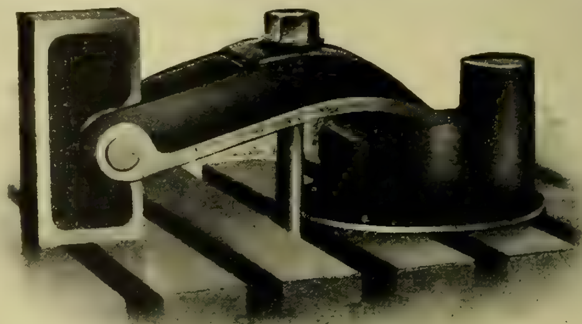


FIG. 9.—"COMBINATION" CRAMP USED AS AN ORDINARY CRAMP. (See p. 713.)

instruments in the circuits, and the producing cost of each loom allotted to a nicety; and if the machine were out of alignment, or if the bearings caused too much friction, this could be detected by the extra load indicated on the ammeter. Then the looms could be placed in any position, thus utilising all the space. The subdivision of power assured fewer stoppages from breakdowns, and power could be more readily distributed to any part of the shed by installing the necessary wiring; and, finally, the direct drive made possible the use of a lighter and more economical building construction.

MICROSTRUCTURE OF GERMAN SILVER.

At a recent meeting of the Birmingham section of the Institute of Metals, a paper on the microstructure of German silver was read by Mr. O. F. Hudson. He said that German silver, like almost all commercial ductile alloys that were rolled and drawn, consisted essentially of crystals of one kind only—a solid solution. Alloys which crystallised as a single solid solution had generally a characteristic microstructure in the ordinary cast state, owing to the fact that each crystal was more or less uneven in composition. Each crystal was said to be cored, and the general structure belonged to that type known as the dendritic or fir tree-like structure. Very slow cooling or suitable annealing, after casting, would eventually give a perfectly homogeneous crystalline material in consequence of the diffusion which took place in each crystal. Ordinary brass, such as the 70-30 alloy, was such a single solid solution, and its cored crystalline or dendritic structure in the cast condition, and its homogeneous crystalline structure in the rolled and annealed condition, was now well known. The crystals of which 70-30 and similar brasses were composed were known as the alpha-crystals of the copper-zinc system, and it was convenient to look upon German silver as consisting of alpha copper-zinc crystals which contained nickel as well as zinc in solution, the effect of the nickel being to destroy their yellow colour and to harden them. The microstructure of German silver thus resembled that of the alpha-brasses, but there appeared to be one point of difference—although only a difference of degree—in that traces of the cores of the original crystals remained after comparatively prolonged annealing at the usual annealing temperatures; in other words, it seemed that diffusion took place much more slowly in German silver than in brass. Apart, however, from this apparent slowness of diffusion, which had also been observed in copper-nickel alloys, the crystalline habit and microstructure of German silver was exactly such as would be expected from its constitution.

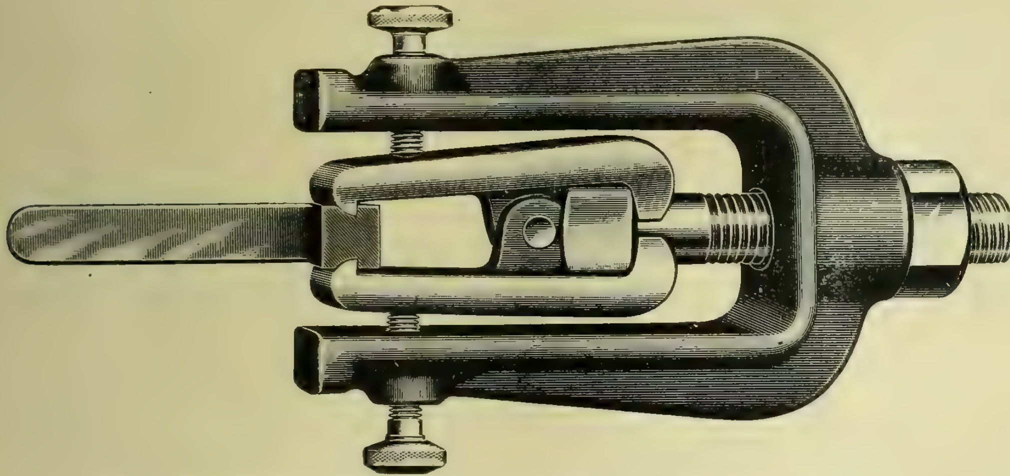


Fig. 10.—Key Extractor. Messrs. Edward G. Herbert, Ltd., Manchester. (See p. 713.)

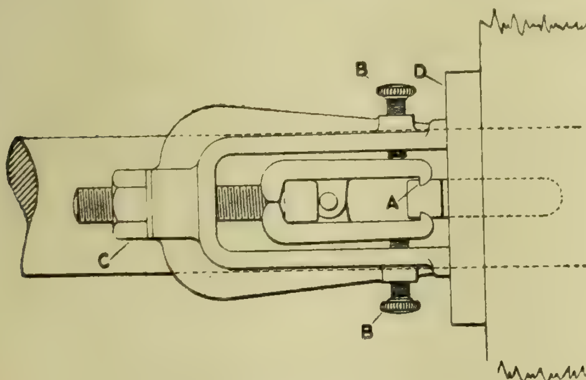


Fig. 11.—Key Extractor. (See p. 713.)

VARIABLE-SPEED HYDRAULIC POWER TRANSMISSION DEVICE FOR MOTOR VEHICLES.

A problem which has for many years enticed inventors, engineers, and makers of self-propelled vehicles has been that of designing a variable-speed hydraulic power-transmission gear for use on such vehicles. The essential elements of such a device are very simple. It is only necessary to connect the driving motor to a pump, to pipe the water delivered by the pump to a hydraulic engine, and pipe the water discharged by the engine back to the pump, and to provide means whereby the pump may vary the quantity of water delivered, while its driving motor runs at constant speed, and the apparatus is complete. But it is quite another matter to devise an apparatus of this sort which will be not only mechanically operative, but commercially practicable, and inventors by the dozen have given up the task, after patience and funds were exhausted. One of the elements essential to success, for example, is high efficiency. If this is not attained the frictional loss will reappear as heat in the power-transmitting liquid. The temperature of this liquid will rapidly increase, until the point is reached where radiation loss will equal the heating effect, and this temperature may be so high as to make the device impracticable. In the early days of the Westinghouse Electric Company, when a variable-speed gear for electric street cars (at that time equipped with low-powered motors) was considered very important, a variable-speed hydraulic gear transmission of the turbine type was worked out and tried, with the result that the water used in the transmission promptly reached a boiling temperature. Experience since that day in the construction of hydraulic brakes has made it clear that very high speed has its drawbacks in hydraulic power transmission.

Besides the necessary high efficiency a hydraulic transmission gear, to be available for use on motor vehicles, must be compact enough to admit of installing it in the limited space available, it must be rugged enough to stand the shocks that the service involves, and light enough that its weight shall not seriously reduce the loading capacity of the car; and, of course, it must be made and sold at a price not in excess of what the results it gives are worth to the user. The variable-speed hydraulic transmission apparatus which is herewith illustrated is not wholly new in principle. Early patents were taken out by H. F. J. Porter, of New York City, on a device which embodied some of the same ideas upon which this gear is constructed, and which found a useful field in turning the turrets of battleships. It was particularly desired, however, to apply the system to the driving of motor vehicles, and a much lighter and simpler machine was desired. The task of undertaking its production was assumed by Charles R. Pratt, and the whole development was put in charge of the Universal Speed Control Company, of 19, Liberty Street, New York.

This gear consists, as shown in Fig. 1, of a reciprocating, multi-cylinder, rotating hydraulic pump, single acting and direct connected to the shaft of the driving engine, and of two reciprocating, multi-cylinder, rotating hydraulic motors, single acting, operated by the pump, and direct connected one to each of the chain-drive sprockets. These three units are enclosed in a sectional cast iron air- and water-tight case, which is attached to the framework of the chassis at three points. This case serves to protect the working parts against physical injury, and also against the weather, and serves as a heat-radiating surface. The working fluid is ordinary machine oil, and besides serving in that capacity, it is used as a lubricant, the gear case being entirely filled with it, so that all moving parts operate submerged in oil. Thus the working fluid provides the most perfect possible lubrication for all the moving parts, and in the simplest manner, while the whole apparatus is preserved from corrosion.

The pump element and the two motor elements of the gear are very similar in design, construction, and operation. All three have rotating cylinder barrels, containing a number of cylinders of equal length and equal bore, arranged symmetrically with regard to the axis of the barrel and with their axes parallel to and equi-distant from its axis. In these cylinders cast-iron plungers operate, having besides the rotating motion about the axis of the cylinder barrel, a reciprocating motion in the cylinders, parallel to the axis of the cylinder barrel, which motion is caused by the fact that the axis of rotation of the drive head—hereafter mentioned—is at an angle with the axis of rotation of the corresponding cylinder barrel. In each unit the plungers are direct-connected by means of short rods to a rotating drive head. The main points in which the pump differs from the motors are, as shown in Fig. 1: (1) The axis of the pump cylinder barrel coincides with the axis of the shaft of the driving engine, while the axis of each motor cylinder barrel is at an angle of 45° with the axis of the corresponding driving sprocket; (2) the drive head, holding the pump piston rods,

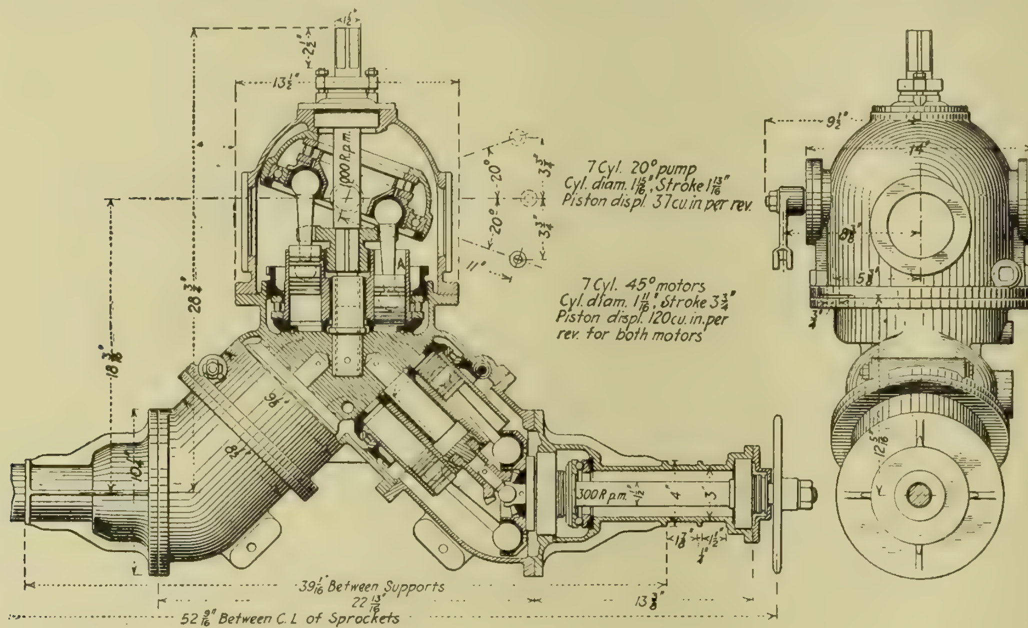


FIG. 1.—SECTION OF VARIABLE-SPEED HYDRAULIC POWER TRANSMISSION GEAR.

is rotated by means of a drive plate, fastened to the shaft of the driving engine, and notched to receive the piston rods, and also the drive head of the pump is so constrained that it rotates about an axis at an angle with the axis of the driving engine shaft, arrangement being made for the variation of this angle from +20° through zero to −20°, whereas the drive head, holding the piston rods of each motor, is fastened to the shaft of the corresponding driving sprocket, with its axis of symmetry and rotation coincident with that of the shaft and fixed; (3) the full stroke of the pump pistons is shorter than that of the motor pistons and, by variation of the angle between the axis of the driving engine shaft and that of the pump drive head, the length of stroke of the pump pistons can be varied from zero to full stroke, while the stroke of the motor pistons is of fixed length; (4) the cylinder barrel of the pump is fastened directly to the shaft of the driving engine, while the cylinder barrel of each motor rotates on a fixed post and is connected, through a small barrel gear, to the shaft of the corresponding driving sprocket.

An analysis of the structural and operating features of the device shows them to be built up around these four basic ideas.

1. The combination of pump and motors gives somewhat the same action as a universal joint in so far as it provides a positive connection between two shafts, rotating about axes at an angle with one another, but without involving the undesirable features of the ordinary universal joint.

2. The working fluid being practically incompressible, and the pump and motor elements having a positive action against it, the fluid forms as positive a link in the power transmission system, between the driving engine and the truck wheels, as if it were a solid rod.

3. The speed of each motor is directly dependent upon the speed of the pump (not the rotative speed, but the capacity of liquid delivery) and upon the speed of the other motor. This follows from the fact that the capacity of the pump, in volume of liquid handled in a given time, must be the same as the combined capacities of the motors for the same time, because the working fluid flows in a closed circuit and under approximately constant pressure, of amount corresponding to the load. Incidentally it may be well to call attention to the fact that the capacity of each element is the product of its speed of rotation multiplied by its piston displacement, as one revolution of each means a complete working cycle of its pistons.

As the motors are symmetrically placed with regard to the pump and to the supply of working fluid, and as they have the same fixed piston displacement, they tend to have the same speed, its value depending on the capacity or quantity of this fluid handled by the pump at any given time. But if one motor becomes retarded or locked, and the pump capacity remains constant, the other motor is forced to speed up sufficiently to make up for the reduction of speed of the first one, in order that the necessary condition above mentioned may be fulfilled, namely, that the combined capacities of the two motor elements must at any time equal the capacity of the pump element. Incidentally it can be readily seen that the pressures on the two motors will be the same, whether their speeds are the same or not, because they are both supplied through similar ports and from the same source So the torque on both driving sprocket shafts will be the same for a given load, regardless of the speed of rotation of each shaft. This whole phenomenon is known as a differential speed, constant torque effect, and, for reasons referred to below, is very much desired in a device of this kind, for the service it has to render.

4. The element of speed variation is provided in two ways in this gear, each method being absolutely independent of the other, positive in its action, and at the same time capable of simultaneous action in connection with the other method. Firstly, the speed may be varied, within wide limits, in the same way as in other cars with the usual type of transmission gear, by keeping the gear in a fixed position and controlling the quality of the mixture fed to the driving engine. Secondly, with the driving engine at constant speed, the speed of the car can be varied from full speed ahead, through zero, to full speed reverse, by variation of the angle between the axis of rotation of its piston casting and that of the drive shaft, thus varying the length of stroke of its pistons, and so varying its piston displacement.

The practical advantages claimed for this hydraulic power transmission and speed regulation system, by the manufacturers, are these:

1. The friction losses and wear and tear, incidental to the use of change gearing, are eliminated and there are no shocks on the transmission system, due to poor handling of the same.

2. The necessity for two brakes on the truck is eliminated. The transmission brake, which was almost universal up to three or four years ago, was a heavy, clumsy device that was always in the way and always giving trouble, and was so unsatisfactory that a large number of manufacturers were forced into the doubtful expedient of replacing it by a second set of brakes on the rear wheels, or by some other equally awkward method. Due to the fact that the speed control is continuous and absolutely positive at all values between full speed ahead and full speed reverse, there is

really no need for any brake at all on the truck, because the braking is accomplished as part of the operation of the gear. Throwing the gear to zero speed, locks the car against travel either ahead or backward, on either an up or a down grade.

3. The necessity for having a clutch in the transmission system, between the driving engine and the change gear, has been eliminated, and with it the continual trouble that attends its use. Scores of different kinds of clutches have been advocated and installed, and all have failed, either by not sticking enough or else by sticking too much. Each variety has been heavy and clumsy, and a constant source of bother while operating and in adjusting, and each has been a device peculiarly subject to wear. This gear, because it allows of continuous variation in the speed of the car from zero to full speed, with the engine running constantly at full speed, does away with the need of a clutch.

4. The gear effects a saving in tyres and drive chains, on slippery streets, and on sharp turns, due to its differential speed, constant torque effect above described.

5. Absolute speed regulation is possible for the reasons already given.

6. Positive drive is obtained at all speeds forward and reverse as explained above.

7. Summing up the weights of all the parts it eliminates, including change gears and case, clutch, and transmission brake, with their necessary auxiliary parts, braces, levers, &c., this gear, with its auxiliary parts, is found to weigh considerably less than those devices, whose separate functions it combines in one piece of equipment.

8. Considering the first cost and the rate of depreciation of this gear, in comparison with the combined figures for the usual change gear, clutch and transmission brake, the former is much the cheaper alternative and possesses, as well, a higher degree of reliability.

The gear above described has been installed on a number of motor trucks, and has been found to work very satisfactorily under actual operating conditions. The pressure on the working fluid varies with the amount of power transmitted, and may reach a value of 1,000lbs. per square inch, under heavy service, but these high pressures can be reduced by increasing the size of the gear, and it is likely that for some classes of service this would be advisable.

In connection with a trial of the gear, mounted on an auto truck chassis, witnessed recently in New York City, the following operating features were observed: The gear could be thrown from full speed to zero or from zero to full speed and the car slowed down or speeded up quickly and evenly without jerks and without noise; the car could be stopped, started or reversed at any time by means of the gear irrespective of the speed of the driving engine or of its direction of rotation; on turning corners the speed of the outside driving sprocket was greater than that of the inside sprocket, due to the differential speed, constant-torque effect above described; and, finally, the jarring, incidental to travel over rough pavements, seemed to have no effect on the gear, and what movement there was, occurred as a unit. In short, the operating characteristics of the gear seemed excellent.—"Engineering News."

Power Required for Turntables.—A committee of the American Association of Railway Electrical Engineers has compiled the following table of power requirements of turntables from tests conducted in the interests of the Association:—

Motor Input for Turntables.

	kw.
69ft. Table—	
Idle	4·5
Turning engine weighing approximately 300,000lbs.	10·0
Turning engine weighing approximately 266,000lbs.	10·3
80ft. Table—	
Turning engine weighing approximately 210,000lbs.	5·6
Turning engine weighing approximately 300,000lbs.	9·6
100ft. Table—	
Turning engine weighing approximately 526,000lbs.	32 to 24

Time required to turn engines approximately one minute.

BOOK REVIEWS.

Elements of Machine Design. Part II. Chiefly on Engine Details, by W. Cawthorne Unwin, F.R.S., LL.D., and A. L. Mellanby, D.Sc. London: Longmans, Green, and Co. 9in. by 6in., 426 pages; price 7s. 6d. net.

Unwin's work on machine design is so well known and has so long ranked as a classic amongst engineers that it is quite unnecessary for us to say anything as to its merits. The feature of later editions has been its steady growth in size owing to the greater range of exposition that has followed the acquisition of wider scientific knowledge of the physical properties of engineering materials, and which in the last 20 years has been more and more reflected in the details of engine design. The appearance of Prof. Mellanby's name on the title page, in view of the position held by Unwin's book, will probably strike most readers, as it did us at first, as a little curious, though this curiosity is allayed by the explanatory note in the preface. It appears that a thorough revision of the treatise being necessary, the author considered it desirable that a fresh mind should be brought to bear upon it. The idea is as creditable to the generous conception of his responsibilities to readers, as his happy choice of Prof. Mellanby is to his judgment. No better selection could have been made, as everyone will agree who is acquainted with Prof. Mellanby's qualifications for the task, and to him, we gather, is due the main credit for the additions and modifications made in the present edition. These are extensive, and have involved new illustrations and descriptions in the chapters devoted to engine cylinders, cranks, eccentrics, pistons, connecting rods, and stuffing-boxes, and which will be of great service to draughtsmen and students in designing these details. The subject of valves and valve gears, as well as condensation and lubrication, are also brought up to date—in fact, there is scarcely a chapter that has not been more or less amended. The illustrations are numerous and clear, and, in fact, nothing appears to have been spared by the publishers to render the get-up worthy of the excellent quality and arrangement of the text. The book is one that no draughtsman or mechanical engineering student should be without.

* * *

Wireless Telegraphy Simply Explained, by H. T. Davidge, D.Sc., M.I.E.E. London: Percival, Marshall, & Co. 7¼in. by 5in., 86 pages; price 6d.

This is one of an admirable series of cheap primers on scientific subjects issued by "The Model Engineer." It is impossible, of course, in the limited space available to touch on more than the elementary outlines and principles of the subject, but so far as is possible within these limits the author has exercised an intelligent selection, and those who are interested in the subject will find this a succinct presentation of it.

BOOKS RECEIVED.

A Text-book of Applied Mechanics and Mechanical Engineering. By Andrew Jamieson, M.Inst.C.E. Ninth edition. London: Charles Griffin & Co. 8in. by 5½in. 412 pp. Price 6/-.

The Beginner's Guide to the Microscope. By Chas. E. Heath. London: Percival, Marshall, & Co. 7in. by 5in. 116 pp. Price 1/- net.

Rugby Engineering Society Proceedings. Vol. IX., Session 1911-12. Rugby: Published by the Society. 8½in. by 5½in. 116 pp. Price 10/6.

Steam Turbines: Their Theory and Construction. By H. Wilda, translated from the German by Chas. Salter, and adapted to English practice. London: Scott, Greenwood, and Son. 7½in. by 5in. 191 pp. Price 3/6 net.

Dictionary of Railway Terms in English-Spanish and Spanish-English. By Anitrés J. R. V. Garcia. London: Constable and Co., Ltd. 9¼in. by 6¼in. 349 pp. Price 12/6 net.

Processes of Flour Manufacture. By Percy A. Amos. London. Longmans, Green, & Co. 7½in. by 5in. 280 pp. Price 4/6 net.

Proceedings of the South Wales Institute of Engineers. No. 4, Vol. XXVIII. Published by the Institute, Park Place, Cardiff. Price 5/-

PRODUCING SOUND STEEL INGOTS BY COMPRESSION.*

BY BENJAMIN TALBOT.

THE problem of segregation and cavities in steel ingots is a subject which has given and is still giving metallurgists, engineers, and operators matter for serious consideration. The question has come more into prominence lately in this country from the desire of railroad engineers to secure a better rail than they have obtained in the past, as the service they now demand is increasing in severity. The rails here are as good as those made in other countries, but the conditions of service and the extremes of climate are more severe, and consequently more breakages occur.

Various reasons have been advanced as to why rails may not be as good in quality to-day as in the past. Some engineers consider that modern methods of manufacturing, designed chiefly to obtain large output, tend to reduce the standard of excellence of more deliberate methods. Others think that 4-ton ingots are worse than those of 2 tons. Again, it is stated that the 100-ton heat in one ladle is too large and is a step in the wrong direction in casting.

My experience upon the question of the size of the ingot is that in rolling mills of 85lbs. to 100lbs. sections, the range of ingot is only practically such that the difference in the size does not help in the question of segregation, cavities, or blow-holes. At Pencoyd, some 16 years ago, two bottom-poured ingots were cast at the same time from the same centre runner, the one being 20in. by 24in. and the other 13in. by 16in. in size. The steel was acid open-hearth, the carbon being 0·43, phosphorus 0·062, sulphur 0·069. At the place where segregation generally concentrates I found: In the larger ingot 0·67 carbon, phosphorus 0·13, sulphur 0·18; in the smaller ingot 0·74 carbon, phosphorus 0·16, sulphur 0·27. Bottom-pouring at that time was considered better for surface defects, but the ingots showed blow-holes all up the surface, and the smaller ingot, in my opinion, was worse in every respect than its larger neighbour.

The question of 100-ton ladle heats is an important matter. In my opinion this is distinctly a step in the wrong direction, as it puts a premium on careless and slovenly casting work. We find that, in order to empty a 100-ton ladle in the necessary time to prevent skulling, very large nozzles are used, probably as large as 2·5in. diam. The pressure of this large quantity of steel rapidly enlarges the nozzle and it would be interesting to know what size the nozzle is when the last portion of the heat is poured. Anyway, large nozzles cause heavy washing up the sides of the moulds and this gives surface defects. There is no doubt smaller ladle heats, poured with as small a nozzle as the heat will permit, give the most satisfactory results.

We now come to the question of producing sound steel ingots for the heavy trades. There are various methods, but we are forced to rule out the old and well-known Whitworth and Harmet press, because of the cost of the process. Others, among whom is Sir Robert Hadfield, suggest the use of a sink-head to feed the pipe which forms by the shrinkage of metal from its liquid to its solid state. To do this effectively some system of keeping the surface fluid must be adopted. There is no doubt that if this is carried out the sinkhead will feed the ingot and the cavity will be in the head. The question to be decided with this method is whether it is commercially applicable to the large output required from a modern rail-mill.

Sound ingots as regards the elimination of blow-holes are produced by means of the well-known powerful deoxidisers, aluminium, silicon, and ferro-titanium. All these deoxidisers have the same effect when used in the necessary varying quantities to produce this. They all produce solid steel, except for the large central cavity. They all diminish segregation. In my experience I have found with well-made steel that an addition of 2 ounces of aluminium to the ton is equal to 0·25 per cent. added silicon, and to 0·10 per cent. metallic titanium in the form of ferro-titanium. These additions will all produce the same characteristic central pipe, and if they are used this piped portion should be discarded in each case. If the rails are milled at each end, which gives a bright surface, as is the practice in England, the pipe is disclosed and the rail rejected by the inspectors. The cost of the aluminium addition is very small; with silicon it is considerable, and with ferro-titanium it is large, to obtain the same result.

If it were not for this large cavity, which may affect as much as 33 per cent. of the ingot, the use of these deoxidisers would improve the quality of the finished rail. It occurred to me that if we were to use a deoxidiser such as aluminium to eliminate blow-holes in the outer envelope of the ingot and then reduce the area of the ingot or the top portion while the centre was liquid, the pipe would not form, and a solid mass would be found in the body of the squeezed ingot.

In analysing and taking sulphur prints off the face of the compressed ingot, which was cut longitudinally through its centre, I came across an interesting discovery. I found that, whenever an ingot was compressed while its centre was liquid, no segregation formed in the centre of the upper part as is usual, but that it was driven to the internal face of the solid envelope in fairly regular percentage over the entire length of the liquid area. The solid outer envelope is the normal steel of the heat and is about 3in., the carbon in this portion in this case being from 0·65 to 0·70. The carbon in the harder portion next this was from 0·75 to 0·80, and in the centre about 0·50. The sulphur and phosphorus also vary in these strata, but as the phosphorus was low in this steel it was not of sufficient amount to be considered.

In ingots compressed while their centre is liquid without the use of a deoxidiser, I find that the centre shrinkage cavity is not formed, but that the blow-holes, which are found in the outer envelope, are not obliterated and can be traced into the rail. For this reason I prefer to use a deoxidiser so as not to have any surface blow-holes which tend to give spongy rails. The method of procedure is as follows: An ingot of at least 20in. by 24in. cross-section is used; 2 ounces of aluminium to the ton of steel is added to the ingot as it is being poured. Aluminium is preferred because of its low cost and its low melting point. It causes a perfectly solid outer envelope to be formed, and solidifies the metal earlier than if no deoxidiser were used. The ingot therefore can be stripped earlier, and it is then put into the soaking-pit to allow the envelope to become thicker, and at the same time have a proper temperature upon its surface for compression. A 20in. by 24in. ingot is reduced to about 18in. by 18in., and it is then returned to the soaking-pit for a proper heating and solidifying of the mass. After this has been accomplished, it is rolled down into a bloom, cropped and passed to the rail-mill. The rail produced has the same characteristic formation as the squeezed ingot, viz., a hard working face, harder ring at back of this, and softer centre.

It is the question of this new formation that we manufacturers have to discuss with railroad engineers and metallurgists. If they accept this new structure with the guarantee that in this formation they have no pipe in a rail, then it will be for manufacturers to consider laying down the necessary preparatory plant to accomplish the liquid compression of the ingot, as it cannot be properly accomplished in any existing rail-mill without largely decreasing the output.

So far the rails produced by this method have been tested under the drop to the British standard specifications and they pass this satisfactorily. The question of taking tensile tests out of the head has still to be considered, as these will vary as they do to-day according to the position selected. In fact, small tensile tests are unsatisfactory at the best, and it would appear that the only satisfactory method would be to have the testing machine large enough to pull the full-sized head.

* Paper read before the American Institute of Mining Engineers.

The Volatility of Metals.—In his presidential address to the Metallurgical Society of the Birmingham University on "The Volatility of Metals," Prof. Thomas Turner said it had been shown that the metals could be divided into four classes, according to whether they lost weight at red heat or not. In some cases complete separation took place; in others alloys might remain or be distilled away. Attempts were being made in different directions to apply these facts, and there was reason to believe that, sooner or later, the fractional separation of metals in a vacuum would play an important part in metallurgy. He suggested that probably the solution of the problem would come by means of the internal electrical heating of the retorts in which the metals were contained.

FIRE EXTINCTION ON SHIPS.

THE discussion on Mr. E. Kilburn Scott's paper on "The Use of Gases for Fire Extinction and Fumigation on Board Ship," an abstract of which appeared in our last issue (see page 685), was resumed at the Institute of Marine Engineers on Monday, November 25th. Mr. Jas. Shanks (Member) presided.

Mr. G. Canning, in opening the discussion, said he thought the practice of blowing steam into the cargo could only be regarded as a check to initial outbreaks. It had been said that the danger to human beings of systems in which odourless gases were used could be overcome by impregnating the gas; but such a method would depend a great deal upon the operator. Sulphur dioxide had an advantage in this respect on account of its distinctive smell. He thought the possibility of a deposit taking place in the pipes was more likely in the case of flue gas than in the SO_2 apparatus. The sulphur dioxide also was more efficacious for fumigation purposes.

Mr. P. Lelow said that with the carbon dioxide system 10 cylinders, each of 40lbs. of liquid gas, would be sufficient to deal with a space of about 42,000 cub. ft. The number of cylinders supplied to a vessel generally was 50, and the average total cost of a new installation would not be more than £350 at the outside. This cost could be much reduced in many cases, as the system could be coupled up to existing pipes. For a space of 100,000 cub. ft. the cost of extinguishing a fire would be about £6. 5s.

Mr. D. N. Hunt said, with regard to the flue gas system, that particulars should be given as to the temperature of the gas being injected, as this considerably affected the rate of diffusion of the gas. He considered it would be very difficult to fit the 6in. pipes required in this system in a very complex vessel. For bunker fires of any magnitude the bunkers would have to be closed down. To blow in an odourless, inert gas when working the coal would probably have fatal effects. In the analysis of flue gas ·5 per cent. of CO had been mentioned. A very thick fire would be required to obtain this, and a difficulty would be experienced in keeping up steam under the circumstances.

Prof. Armstrong said the carbon dioxide, sulphur dioxide, steam, and flue gas systems were all based on the same principle, the reduction of the oxygen in the air, and the problem was to determine which of the four would best serve the purpose. The carbon dioxide system required a somewhat expensive equipment of iron cylinders filled with compressed gas, and there was the disadvantage that when the supply was exhausted, as it might be on a long voyage, the system would be of no value. With the sulphur dioxide system there was the same difficulty, with the additional objection that its use would injuriously affect the metalwork of the ship, and certain cargoes. Steam had the advantage that it was always there as long as the boilers were at work. The flue gas system also had that advantage. It was very ingenious, as it utilised a waste material, which could be obtained as long as the coal supply lasted, and which had practically the same power as the other gases of acting as an extinctive agent, while being without their deleterious effect upon the ship and cargo.

Mr. J. Craig said the temperature of the flue gas was reduced to about 100° Fah. when put into the cargo. Experiments had proved that there was no deposit in the pipes with this system. A cooling process, in his opinion, was a necessity in fire extinction. Dr. G. Harker pointed out that the flue gas itself had a distinctive odour. Gases such as CO_2 must have a greater penetrative effect than sulphur dioxide, as they were not absorbed. He gave particulars of actual cooling and other experiments.

The hon. secretary read a contribution from the author, Mr. E. Kilburn Scott, who was unable to be present. Mr. Scott considered the use of inert gases to be especially valuable for the prevention of spontaneous combustion in cargoes such as coal, cotton, and wool. One of the great advantages of the flue gas system was that in fumigating it could be used when the holds were full of cargo without the cargo being injured. A distinctive odour could be given to inert gases by the addition of a very small quantity of certain substances, such as mustard oil or carbon bisulphide.

THE INSTITUTE OF METALS.

As was announced at the autumn meeting of the Institute held in London in September last, the annual general meeting of the Institute, which in former years has been held in January, will next year take place in the spring, the dates selected by the Council being March 11th and 12th, 1913. By the courtesy of the Institution of Mechanical Engineers the meeting will again take place at Storey's Gate, Westminster, S.W. In the evening of the first day the fourth annual dinner will take place. Amongst the papers that will be presented will be Dr. G. D. Bengough's Second Report to the Corrosion Committee, in which he will deal with the results obtained from the experimental condenser which has been running continuously at Liverpool since the beginning of April. Various data have been collected concerning temperature, amount of water condensed, vacuum, &c., which show that the conditions to which the condenser tubes have been subjected reproduce, as closely as can be expected, average conditions of service in the mercantile marine. Three tubes of each composition represented in the plant will be withdrawn in December, cut up longitudinally, and subjected to a detailed examination, chemical and physical. The research into the causes of the corrosion of condenser tubes, which is costing £100 per annum, will not be completed for another two and a half years. As the funds at present in hand will not permit of the research being carried on beyond the end of the present year the committee earnestly hope that individuals and firms interested in the subject will afford the necessary financial assistance, which should be sent to Mr. G. Shaw Scott, M.Sc., the Secretary of the Institute of Metals, Caxton House, Westminster, S.W.

As a result of a suggestion contained in a paper on "The Nomenclature of Alloys," read by Dr. W. Rosenhain, B.A., before the Institute of Metals in January last, a committee consisting of representatives of the Institute of Metals and allied societies has been appointed under the name of the Nomenclature Committee, and will shortly hold its first meeting. The following representatives on this committee have been appointed: Institute of Metals—Dr. W. Rosenhain, B.A. (Chairman of Committee), Mr. G. A. Boeddicker, Prof. H. C. H. Carpenter, M.A., Ph.D., Dr. Cecil H. Desch, Engineer Rear-Admiral G. G. Goodwin, R.N., Mr. G. Hughes, Sir Gerard Muntz, Bart., Mr. A. E. Seaton, and Prof. T. Turner, M.Sc.; Institution of Electrical Engineers, Mr. W. Murray Morrison; Institution of Mechanical Engineers, Mr. G. Hughes; Institution of Naval Architects, Sir W. E. Smith, C.B.; Institution of Engineers and Shipbuilders in Scotland, Mr. Alexander Cleghorn; North-east Coast Institution of Engineers and Shipbuilders, the Hon. Sir C. A. Parsons, K.C.B.; Society of Chemical Industry, Prof. W. R. Hodgkinson, Ph.D. It is proposed that this list shall be further extended as may be found desirable.

Another new committee has been appointed by the Council for the purpose of assisting the Dominions Royal Commission in their enquiry into the question of the supply of non-ferrous metals and ores in this country. A report dealing with this subject is being prepared by the committee, of which Prof. T. Turner, M.Sc., is the honorary secretary, other members being: Mr. G. A. Boeddicker, Mr. W. Murray Morrison, Sir Gerard Muntz, Bart., and Mr. Leonard Sumner, M.Sc.

A ballot for the election of new members will take place this month. In order that their names may be included in the ballot, applicants for membership should send in their forms to the Secretary on or before December 16th.

Apparatus for Testing Gas in Mines.—Dr. Leonard Levy recently demonstrated before the Society of Chemical Industry in London two forms of portable apparatus for testing the exact composition of the air in mines. The first apparatus is for determining the percentage of fire-damp, and is based on the ordinary principles of gas analysis. The air to be analysed is drawn over a platinum wire heated by an electric current, and the methane present is estimated by the decrease in volume that takes place as a result of combustion. The second form, which is more elaborate, but which incorporates these two essential features, makes it possible rapidly to estimate the percentages of carbon dioxide, fire-damp, and oxygen, the usual absorbents being employed. It may be added that there is no risk of sparking taking place, even if the apparatus gets accidentally broken.

NOTES ON PRODUCER GAS POWER.*

BY H. F. SMITH.

In the manufacture of producer gas there are three distinct steps: (1) The preparation of a suitable blast consisting of the various elements which it is desired to combine with the fuel. (2) Bringing about a combination of the elements in the blast with the fuel to be gasified. (3) Cooling and cleaning the gas to render the same suitable for use.

In producer gas for power it is of the highest importance that the gas should have as nearly uniform composition as possible. As a first step towards the production of uniform gas, it is necessary that the blast supplied to the producer should be of uniform composition. In other words, a constant ratio must be maintained between the oxygen and water vapour in the blast Without taking time to go into detail concerning the various methods that have been suggested for this purpose, it may be remarked that so far only one method seems to meet all requirements. It is a well-known principle in physics that air at a given temperature will take up a definite proportion of water vapour and no more. It will take up water by evaporation until its point of saturation is reached, provided, of course, that it is kept in contact with a sufficient surface of water for a sufficient time for this saturation to occur. The temperature of saturated air, therefore, is a direct measure of the amount of moisture contained in it, and if we supply to the producer saturated air at a constant temperature, we will supply a blast containing a definite and constant proportion of moisture. This method of vapour control is the only one that compensates fully for the normal daily and seasonal variations in atmospheric moisture. All mechanical appliances for measuring off a definite amount of water to be evaporated into steam are defective in that, however perfect they may be intrinsically, they cannot possibly compensate for variation in the moisture content of the air supplied to the conditioning apparatus. The air for the blast can be readily heated and conditioned with regard tc moisture by bringing it into contact with an extended surface of hot water. In this way there is no direct introduction of vapour into the blast. The water, of course, must be below boiling, and the evaporation will never be more than sufficient to saturate the air at the temperature at which it leaves contact with the water. The condition with respect to moisture of air saturated in this manner can be readily determined by noting its temperature. It is, of course, important to have the conditioning apparatus designed so that no water spray will be carried forward mechanically in the blast, but where hot water is used for conditioning, this is not at all difficult. Steam cannot be satisfactorily employed for this purpose for the reason that it is not practically possible to maintain an absolutely constant condition of steam, and any variation in the condition of the steam will result in a corresponding variation in the actual degree of saturation without necessarily changing the temperature of the blast. The writer has frequently observed that there is a material difference in the percentage of moisture carried forward in a blast saturated to a given temperature by hot water, and a blast raised to the same temperature by the admixture of steam. It would seem likely that this is due in no small measure to the fact that where steam is used to saturate the blast, not only is moisture carried into the blast in liquid form with the steam, but a portion of the steam is condensed to provide the necessary heat for raising the temperature of the air, and these various small particles of liquid water are carried forward mechanically into the fuel bed. As a rule, therefore, a blast saturated to a given temperature with steam will carry more moisture than a blast saturated to the same temperature by the hot-water process. The method of saturation by contact with hot water has a further advantage in that it is favourable to automatic control. On suddenly-varying loads the thermal inertia of the entire apparatus tends to prevent a change in saturation conditions, since this would involve a change in temperature, and this would be automatically resisted by all warm parts of the apparatus which would surrender heat rapidly to prevent such a change. It is a relatively simple matter also to provide automatic control by means of a thermostat located to register the temperature of the blast leaving the conditioning apparatus, and to regulate the supply of hot water as may be required to maintain this temperature constant.

In bringing about the combination of the various elements of the blast with the fuel in the producer, many items demand consideration. We have noted above that the conditions determining the rate of producer reactions are: (*a*) Temperature; (*b*) surface of contact between the blast and fuel; (*c*) time of contact between the blast and fuel. The temperature at which the fuel bed may be maintained for continuous operation is determined by the fusing point of the ash contained in the fuel. The use of coals having ash fusible at a relatively low temperature demands the construction of a producer not only of greater sectional area, but of greater depth than would be required for a fuel that would permit the use of higher temperatures. A brief consideration will show that the size of fuel fired to the producer has considerable influence both on the surface of contact and time of contact between the blast and fuel. If we assume a producer of given sectional area, the time required for the blast to pass through a given depth of fuel would be directly proportional to the total area of voids in the fuel bed. The larger the pieces of fuel the greater the percentage of voids, and consequently the slower the rate of blast passage through the bed. On the other hand, the smaller the pieces of fuel the greater would be the ratio of surface to mass, and consequently the greater would be the surface exposed to the action of the blast. We have, therefore, with regard to size of fuel, two variables, the resultant of which we would expect to reach a maximum for some particular size neither the largest nor smallest. This, indeed, is found to be the case. With anthracite, for example, the maximum capacity for a given depth and sectional area of producer is obtained with coal that will grade through $\frac{7}{8}$in. and over $\frac{9}{16}$in. squar mesh screen. This coal is ordinarily marketed as pea. Larger sizes of anthracite, while permitting a slower rate of gas passage and a longer time of contact, present a surface so much reduced in total area that the capacity of the machine suffers distinctly. On the other hand, small fuel, while presenting an enormous surface, so completely occupies the voids that the gas velocity through the relative small area remaining is so high that the time of contact is insufficient, and the producer capacity is accordingly reduced.

In the actual design of the generator chamber it is important not only to proportion the diameter of the producer and depth of fuel bed properly in relation to the fuel to be used, but it is also very necessary to take some steps to ensure a uniform distribution of blast over the entire sectional area of the producer. Since temperature is the limiting factor, if any portion of the fuel bed is driven at a more rapid rate than normal this portion must necessarily reach a higher temperature, and may even exceed the permissible temperature for the particular coal used, and cause fusion of the ash and clinkering. The principal difficulty in securing blast distribution is in preventing too rapid driving next to the producer lining. There is always a tendency for the fuel bed to be more porous and open next to the lining than elsewhere, and if the bed is simply maintained on a flat grate with a fuel bed of uniform depth discharging into a gas space extending over the whole upper surface of the producer section, the temperature next to the lining will be much higher than in the centre of the fuel bed. It is accordingly very desirable to arrange the fuel bed so that the resistance next to the lining will be augmented. In the ordinary water-bottom type of producer this is frequently accomplished by locating the air inlet in the centre of the fuel bed, discharging the blast into the fire through a central tuyere, so that to reach the lining it is necessary to pass horizontally through a considerable depth of fuel. This would be a highly desirable method were it not for the fact that the concentration of the blast has a tendency to increase the rate of combustion in the immediate neighbourhood of the tuyere, thereby raising the temperature at this point and introducing clinker trouble. Since the highest temperature attained in the fuel bed is usually at or near the point at which the air first enters the fire, it is plain that for uniform low-temperature conditions the grates should have as large surface as possible. This condition can

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easily be met and the low resistance of the fuel bed next to the lining, compensated for by increasing the depth of fuel next to the lining, or by locating the gas outlet centrally in the top of the generator chamber. It is obviously radically wrong to locate the fuel magazine in the centre, since this procedure increases the resistance in the centre of the fuel bed where it is already high, and makes hard driving and high temperature next to the producer lining inevitable. On account of the low operating temperatures permissible, if clinker troubles are to be avoided, it is necessary not only to adopt very moderate driving rates, but to allow the greatest possible amount of time of contact between blast and fuel by making the active part of the fire very deep. In this way the equilibrium condition for the ratio of CO to CO_2 can be more nearly approached, and the disadvantages of low producer temperatures from a gas-making standpoint compensated for in no small degree. On anthracite the rate of driving should not ordinarily exceed 8lbs. per square foot per hour. For bituminous coals the rate may be considerably raised, and on good fuel may even go to twice this figure. The depth of fuel bed in either case should preferably be not less than 5ft.

A very deep fuel bed has other advantages than simply to contribute to producer efficiency. When the producer is operating under varying loads, and particularly when a suction producer is supplying a gas engine, it must be prepared to meet sudden demands for increase of gas without too much alteration in gas quality. When the producer is operating at light load it is probable that not more than 16in. or 18in. of the fire is engaged in active combustion. However, the fuel lying immediately above this is heated red hot simply by contact with the hot gases passing from the fire below. This red-hot fuel is capable of entering into immediate combustion as soon as any air is brought into contact with it. Accordingly, when a sudden load is thrown on the engine, and a correspondingly sudden demand for gas is made, the increased velocity of flow through the fuel bed immediately draws air into the upper layers which, although red hot, have not been chemically active. These upper layers are capable of instantly supporting combustion, and they contribute in this way to maintaining uniform gas quality, and permit the producer to respond to variations in load that could not otherwise be met. The large mass of fuel within the producer has a correspondingly large store of thermal energy, and exerts by its mass a very desirable steadying effect on the whole gas-making process. The producer is accordingly able to carry over sudden demands simply by virtue of heat energy previously stored in the fuel bed, which may be gradually restored later, and thus performs, to some extent, the function of a thermal flywheel.

When we consider the gasification of coals containing volatile matter, another element is introduced which requires most careful attention. Not only does the presence of hydrocarbons affect the method of gasification in the producer by introducing a distillation process which must be carried on at the expense of heat generated in the gasification of the fixed carbon, but the problem of maintaining a uniform gas quality is complicated by the rich hydrocarbons from the destructive distillation of the fuel, and the cleaning of the gas must be carried out with much greater thoroughness. It is in connection with this class of fuels that the most interesting work is being done at the present time in the field of producer design. It is accordingly not inappropriate that the various plans that have been suggested and promoted for the gasification of bituminous fuels should be briefly discussed.

The remarks in this connection relate, of course, almost entirely to the production of gas for power purposes, although the importance of uniform gas quality for furnace work is coming daily into greater prominence. The ordinary type of up-draught producer for bituminous coal cannot possibly produce a uniform grade of gas. Not only are the methods employed for saturating the blast utterly inconsistent with close regulation of the blast quality, but the ordinary method of distilling the volatile matter from the coal is such as to make uniform gas production impossible. The distillation of volatile hydrocarbons from bituminous coal is a process that absorbs considerable heat. It can take place, therefore, only where this heat is being supplied either by combustion in the immediate neighbourhood of the fuel being distilled, or by contact with hot gases proceeding from a portion of the fuel bed which is maintained at high temperature. In the ordinary type of fuel producer, the fresh fuel is simply dumped on to the top of the fuel bed and exposed to the hot gases issuing from the burning fuel immediately beneath. When a fresh charge of fuel is dropped, a rapid evolution of hydrocarbon gases results, with a corresponding rapid increase in gas value. After the fuel has been exposed to this temperature for some time, the production of volatile gases diminishes, but the coking of the fuel is not complete until the coal has descended into the very hottest region of the fire, since very high temperatures are necessary to drive off the last volatile matter from the coal. To overcome the difficulty from variation in gas quality resulting from sudden distillation of hydrocarbons from the coal, two general methods have been suggested; first, by regulating the rate of distillation of hydrocarbons, and second, by so altering the characteristics of the distilled gases by suitable chemical reactions that they will not differ materially in heating value from the gas resulting from the gasification of fixed carbon. Both of these processes are to some extent successful, and the degree to which each may be successfully applied is a matter of no little interest. The chief argument in favour of the first method, namely, regulating the rate of distillation without altering the characteristics of the distilled gases, lies in the fact that this process permits the use of a very simple type of up-draught producer, and results in the production of gas that is of materially higher heating value per cubic foot than can be produced from fixed carbon alone. These advantages are not to be considered lightly. Simplicity of apparatus is certainly much to be desired, and the production of gas high in heat value has an important bearing on the cost of gas power equipment, since the power that can be developed by an engine of given cylinder displacement depends, to a considerable degree, on the minimum heat value of gas supplied. The cost of equipment, therefore, to satisfactorily accomplish a given work will be materially lower when a gas of high heat value is produced. It has been maintained that more satisfactory results can be secured from low heat-value gas, since the engine efficiency can be raised, by increasing the compression, to a point where just as much power can be developed as with a richer gas. While this is undoubtedly true, this increase in power and efficiency is always accompanied by a necessary increase in the strains on the various working parts sufficient to demand heavier construction, or, lacking this, the operation of the plant on a lower factor of safety.

The chief interest that attaches to the various means that have been suggested for altering the chemical character of the distillation products from bituminous fuel, lies in the possibility of eliminating tar by this process, and thereby simplifying the cleaning plant required. Two methods have been most frequently employed for treating the hydrocarbon vapours to alter their chemical characteristics: First, decomposition by heat; second, combustion with oxygen. If tar-free gas is to be produced by either of these processes, it is essential that the conditions for chemical alteration of the volatile hydrocarbons must be maintained until the final trace of volatile matter has been driven from the coal. In other words, the coking of the fuel must be absolutely complete before the coke can be considered as fixed carbon and treated differently than would be permissible for the bituminous fuel from which it is produced. This means that the distillation process whereby the volatile matter is separated from the fixed carbon in the fuel must be unusually thorough. It is interesting to note that ordinary gas-house coke is not by any means sufficiently carbonised to be considered fixed carbon for producer purposes. Likewise, charcoal contains too much bituminous matter to be used in an ordinary up-draught producer without special provision for removing tar from the gas before it is passed to the engine. The process of distillation whereby the volatile matter is driven from the coal must be materially more thorough than that employed in the ordinary bench gas process, or in the production of charcoal, if tar-free gas is to be generated from it. If we assume, however, that this distillation process has been satisfactorily carried out, and the volatile matter completely separated from the fixed carbon, its sub-

sequent treatment demands further consideration. These hydrocarbons can be completely converted into fixed gas and carbon by exposure to a sufficiently high temperature for a sufficient length of time. It would seem, therefore, that all that would be required would be to pass the volatile hydrocarbons, as liberated, through a bed of incandescent fuel, thereby heating them to a high temperature, and bringing about their decomposition into carbon and fixed gas. Unfortunately, while it is relatively easy to bring about a partial decomposition in this way by the use of heat alone, it is not by any means so easy to make the decomposition complete. The tendency of hydrocarbons treated in this manner is to split up into two portions, one of which is a fixed gas and the other a mixture of hydrocarbons more dense than the original body. This process may be continued to its finality, but as each step of the reaction takes place the next requires the use of higher temperatures and longer time of exposure for its completion. If a sufficiently high temperature could be maintained within the fuel bed, and the hydrocarbon gases brought to this high temperature and held there for a sufficient length of time, the production of perfectly tar-free gas from these hydrocarbons could be accomplished. Generally, however, it is found that the temperatures required and the time of contact necessary for such a complete reduction are both beyond the range permissible in producer practice.

A more ideal method for handling these hydrocarbons would seem to be offered by the process of complete combustion. The hydrocarbon vapours given off by distillation are extremely inflammable. If they are completely burned with air to their elementary products of combustion, namely, CO_2 and water vapour, all elements that might possibly contribute to the production of tar or lamp-black would be removed. These products of combustion would be very highly heated by their combination with oxygen, and could easily be regenerated into combustible gas by being passed down through the fixed carbon remaining from the destructive distillation. In this way a perfectly clean gas, free from either tar or lamp-black and of uniform chemical composition, and consequently of uniform heat value, could be produced.

Many producers have been designed in an effort to incorporate this principle in a commercial machine. Two fundamental difficulties are encountered which are independent of any question of design, and which have a very material bearing on the success of this type of apparatus. The first of these is the difficulty of securing sufficient completeness in the coking or distillation process. The thorough coking of any fuel containing a considerable quantity of bituminous matter is a process that requires not only high temperature, but considerable time. The fuel is heated from without inward, and time is required for the heat to penetrate to the interior of the lump of coal. This penetration is continually hindered by the current of volatile matter that is passing out towards the surface of the fuel from within. Driving off the last traces of volatile matter requires a very high temperature, and the combined requirements of high temperature and long time of exposure make a difficult problem. Of course, the complete distillation of hydrocarbons is absolutely essential in all double-draught machines; that is to say, in machines in which the fixed carbon is gasified up-draught after the manner of the ordinary up-draught producer. It must be assumed, in machines of this type, that nothing but fixed carbon is delivered in the up-draught zone, since any volatiles proceeding from this part of the producer would pass out of the gas outlet unfixed. This process of distillation can be materially hastened and made more complete if a portion of the fixed carbon is consumed during the process of distillation. This not only materially increases the available heat, but, by reducing the size of the lumps of fuel by removing carbon from the surface, it favours more rapid coking. However, any combustion of fixed carbon increases the second difficulty, of which we will now make mention.

It is evident that if complete reduction of the hydrocarbon vapours without formation of either tar or lamp-black is to be attempted, these must be completely burned to their ultimate products of combustion—carbonic acid and water vapour. It is therefore pertinent to enquire whether or not there is sufficient fixed carbon in the fuel to reduce the products of combustion arising from the complete burning of the volatile hydrocarbons. In order to bring this matter clearly to mind, the writer has selected four more or less characteristic American coals. The chemical analysis of these fuels is taken from the U.S. Geological Survey report. The first of these is Pocahontas. Chemical analysis of this coal shows a total of 90 per cent. carbon, of which 80 per cent. is fixed carbon and 10 per cent. is combined with 4·6 per cent. hydrogen to make a total of 14·6 per cent. volatile matter. To completely burn this volatile matter would require for the carbon 27 parts by weight of oxygen to form CO_2 and for the hydrogen 37 parts by weight of oxygen to form H_2O. These products of combustion, to be completely reduced to CO and H, would react with 50 parts by weight of fixed carbon. The Pocahontas coal, however, contains 80 parts by weight of fixed carbon, so that there would be, with this fuel, an ample supply of fixed carbon to reduce completely the products of combustion of the volatile matter, and with a sufficient margin to cover contingencies and imperfections in the process. Considering in the same way a West Virginia coal from the Fairmont District, we have 63 per cent. fixed carbon and 28·6 per cent. volatile matter. If this volatile matter is completely burned, 56 parts by weight of fixed carbon would be required to reduce the products of combustion. This coal contains 63 per cent. by weight of fixed carbon, so that we can reasonably expect this process to be practical with coal of this quality if no fixed carbon is burned during the distillation process. If we consider, in like manner, a characteristic Illinois coal, we find it to contain 50 per cent. fixed carbon and 27 per cent. volatile matter. To completely reduce the products of combustion of this volatile matter, 57 per cent. of fixed carbon would be required. With this grade of coal, there-

Coal.	Fixed Carbon.	Volatile.		Oxygen to burn volatile to CO_2 and H_2O.	Carbon necessary to reduce CO_2 and H_2O from combustion of volatile to CO and H.
	C.	C.	H.		
Pocahontas	80	10	4·6	64	38
W. Virginia	63	23	5·6	106	56
Illinois	50	21	6·1	104	57
Indiana	49	25	6·2	116	61

fore, it would seem to be impossible to carry out this sort of producer process efficiently, even if we assume that the volatile matter could be completely driven from the coal without loss of fixed carbon, and that these volatile products could be completely burned without excess of air. Since neither of these propositions is commercially practical, it is seen to be a physical impossibility to operate a producer on Illinois bituminous coal on this principle. Considering in the same way a characteristic Indiana coal, we find the fixed carbon to be 49 per cent., the volatile combustible 31 per cent., and the fixed carbon required to reduce completely the products of combustion resulting from the volatile combustible material to be 61 per cent. There is available in this coal, however, only 49 per cent. fixed carbon. It is therefore seen that this coal is also impracticable for this method of operation. Of the four coals considered, it is plain, if any reasonable allowance is made for the unavoidable imperfections of the process, that only one, namely, the Pocahontas coal, possesses the necessary characteristics to permit this process to be successfully carried out. The great majority of bituminous fuels available, in this country at least, are not amenable to this process of treatment owing to inherent defects in their composition. This process cannot be applied with any prospect of commercial success on fuels containing less than about 75 per cent. fixed carbon. When fuels containing less fixed carbon than this are used, the process must be more or less incomplete at one point or another. If the volatiles are completely reduced so that neither tar nor lamp-black are formed, then the producer operation must necessarily be inefficient, since a portion of the products of combustion must pass forward unreduced, and stand as an unavoidable loss in the gasification process. If, however, the combustion of the volatile matter is not complete, that is to say, if insufficient air is supplied to completely burn them, then the production of tar or lamp-black is unavoidable. Neither of these processes is carried

out completely in any form of commercial apparatus. The ordinary down-draught producer may be taken as representative of most of the attempts that have been made in this direction. In this the distillation process is materially aided by the combustion of a part of the fixed carbon. The volatile matter is partially burned in contact with an insufficient supply of air, this process resulting in the liberation of lamp-black from the hydrocarbons. Those hydrocarbons that escape combustion, either complete or partial, are to some extent broken up in passing through the incandescent carbon in the lower levels of the producer and converted by heat into fixed gas and tar, or, if the fuel bed temperature be sufficiently high, into fixed gas and coke. No producer yet designed for bituminous fuel has succeeded in producing a gas that is at all times sufficiently clean to make the use of efficient cleaning unnecessary.

The materials to be removed from gas in the cleaning process vary with the fuel from which the gas is derived. With blastfurnace gas the impurities to be removed consist almost entirely of inorganic dust arising from the iron ore and limestone fired to the furnace. In gas from anthracite, the principal impurities to be removed, aside from the relatively small amount of fine ash which is carried over, consist almost entirely of sulphur or some compound of sulphur in a finely-divided state. The deposit occurring in piping and valves from anthracite producers always contains a large percentage of sulphur, if this substance is found in any considerable quantity in the coal. It is probable that this sulphur dust originates from the spontaneous decomposition of various sulphur compounds in the gas, many of which can undergo chemical changes at ordinary temperatures with the liberation of sulphur dust. Gas from bituminous coal will require purification from tar or lamp-black or both, depending on the processes used in treating the hydrocarbons in the coal. In connection with the utilisation of gas from bituminous coal, the point on which the most serious question is usually raised is on this matter of gas cleanness, and particularly on freedom from tar.

In order that some idea may be gotten of the problem involved in purifying gas from bituminous coal, the writer has recently conducted some investigations that will enable him to present to you a few figures representing, approximately at least, the characteristics of tar in producer gas. In raw bituminous producer gas the tar is carried in the form of minute particles, or, as it is commonly designated, as tar fog. In the particular case investigated by the writer, the gas carried a total of approximately 4 grains of tar per cubic foot. The tar particles were found to vary in size from about 0·00008in. to 0·00015in. diam., the average size being in the neighbourhood of 0·00010in. The number of tar particles was found to be somewhere in the neighbourhood of 20,000,000 per cubic inch. These particles are so small and their ratio of surface to mass so great that they are influenced almost entirely by their surface relations with other bodies and very slightly by their mass. The viscosity of the gas is so great that the tar particles move through it very slowly. The surface action predominates to such an extent that it is impossible to separate the tar particles from the gas by centrifugal force alone, even though the difference in density between the gas and tar fog is very great. It might be remarked here that the so-called centrifugal tar extractors do not operate by the action of centrifugal force on the tar particles, but in an entirely different manner. These particles are so minute that any ordinary filtering medium will not trap them. The particles will pass freely through the meshes of almost any woven fabric. When passed slowly through as much as ¼in. of wood felt, the issuing gas still contains a considerable quantity of the tar fog. In view of the smallness, the elusive property, and enormous number of these particles, the results that can be attained in cleaning producer gas with suitable appliances are certainly remarkable. There are a number of systems of cleaning producer gas that are more than 99 per cent. efficient; that is to say, of the 20,000,000 tar particles contained in a cubic inch of raw gas it is comparatively easy to remove 19,800,000 by suitable processes. When the quantity of gas required in a power plant of very moderate dimensions is taken into consideration, the work to be done by a scrubbing plant assumes enormous proportions. A 200 h.p. plant, for example, will use approximately 16,000 cub. ft. of gas per hour. In a plant of this size the cleaning apparatus is under the necessity of removing from the gas 140,000,000,000 tar particles per second. No practical method has yet been devised for removing absolutely all of the tar from the gas, but by the use of appliances that need not be at all complicated, it is possible to bring the cleaning plant to a very high degree of effectiveness. It is at present not beyond the range of possibility to produce, in a commercial way, gas containing not more than 0·001 of a grain per cubic foot. This implies a scrubbing efficiency of 99·99 per cent. Gas may be considered sufficiently clean for gas engine use under any ordinary conditions if the impurities are reduced to less than 0·03 of a grain per cubic foot. From this it would seem that the margin between the necessary degree of gas cleanness and the possible degree of gas cleanness is sufficient to constitute an ample factor of safety.

COMPARISON OF FIVE METHODS USED TO MEASURE HARDNESS.

In order to ascertain the concordance which might be expected in the five leading instruments for testing the hardness of metals, an investigation was made at the United States Bureau of Standards, the results of which are recorded by Mr. R. P. Devries in a report recently issued. The static tests of hardness studied are the cone and Brinnell sphere. The dynamic tests are the Shore scleroscope, Brinnell sphere, and Ballantine. The Bauer drill test for measuring the workability of metals is also included. The tests were made on a series of metals which ranged from very

Hardness Numerals of Different Metals by Five Methods of Test.

Metal.	Shore scleroscope.	Hardness numeral.				Bauer drill test.	Ballantine test.
		Brinnell.		Cone 90° cone	Test, 60° cone		
		$\frac{P}{2\pi tR^1}$	$\frac{P}{t}$				
Carbon steel	86·1	641	4550	..	..	..	3·2
Silicon steel	33·6	261	865	331	130	..	3·0
Manganese steel	29·5	179	641	368	124	..	3·3
Cast iron No. 1........	33·3	149	538	191	68	..	3·2
Cast iron No. 2........	32·9	172	590	231	79	2·29	3·3
Bessemer steel	26·6	188	428	260	76	..	3·3
Tool steel	37·8	289	1230	..	..	..	3·3
Cu.-Sn. alloy 1........	42·4	110	460	130	50	·73	3·1
Cu.-Sn. alloy 2........	25·5	105	323	149	54	1·04	3·2
Cu.-Sn. alloy 3........	22·1	94	289	122	48	1·24	3·4
Copper 4	15	89	235	114	38	1·88	3·2

hard steels to comparatively soft alloys. The laws governing the resistance to indentation are experimentally deduced for spheres of different sizes and cones of different degrees of angular opening. The effect of elastic deformation of the sphere upon the results of sphere tests is determined by means of a method which involves the exact measurement of the depth of indentation. This method of measurement is also applied to the cone tests. The study of the individual methods shows (1) the possibility of obtaining rational hardness numerals for the cone and sphere tests, and (2) that the dynamic tests for hardness do not agree in general with the results of static tests.

Enquiry into the Failure of a Chain.—The adjourned inquest on the four victims of the accident at the Globe Foundry, of Messrs. Towler & Co., Leeds, was held on the 29th ult. The accident, as mentioned in our last issue (see page 693), was caused by the breaking of a chain holding a ladle containing three and a half tons of molten metal. The ladle upset, and the contents were scattered upon the men standing by. It was stated by the foreman of the works that the chain had broken before, though it had not dropped the ladle. This failure had not been reported to the Factory Inspector. The jury found that the men met their deaths accidentally by the upsetting of the ladle, due to a defective link. They recommended more careful supervision after the repair of a chain and also periodic inspection by an expert.

THE USES OF PLATINUM.

THE application of platinum in the arts is extremely varied, and would be even far more extended if it were not for the high price and the limited supply of the metal. A paper on the subject was recently presented at a meeting of the Franklin Institute by Mr. H. F. Keller, Ph.D., who said that platinum had not inaptly been called "white gold." Its physical and chemical properties closely resembled those of the yellow metal with which it was generally associated in Nature. But in addition to the many virtues which it shared with gold, platinum had several most valuable properties of its own, and it was chiefly to these that it owed its many uses in science and in the arts. On account of the great difficulties which had to be overcome in freeing platinum from the other metals with which it occurred in Nature, it was many years after the discovery of the metal before it found any practical applications.

The first platinum crucible was said to have been made by Achard. It must have been a very crude affair. The German chemist's process of rendering platinum malleable was improved by the Paris goldsmith Jeannetty, who enjoyed a great reputation for the platinum goods he turned out. The prototypes of the meter and kilogram were, he understood, made by his process. At the beginning of the 19th century vessels made of platinum were still so scarce and costly that very few chemists could boast of possessing such apparatus. It was not until the London firm of Johnson and Matthey and the chemist Wollaston developed their method of rendering platinum workable that wire, foil, crucibles, and other articles made of the metal came into more general use. As early as 1809 Johnson & Matthey manufactured a platinum still for the concentration of sulphuric acid which weighed 424ozs.

It would, he observed, be difficult to overestimate the effects which the use of platinum apparatus had on the progress of the sciences and arts. Writing in 1844, Liebig thus characterised the part which platinum played in the chemical laboratory: "Without platinum it would be quite impossible to carry out a mineral analysis. To render the sample soluble, it must first be fused with suitable reagents. Glass and porcelain, or any other non-metallic substance of which crucibles were made, would be rapidly destroyed in this operation, while crucibles made of gold or silver would melt at the high temperatures at which the fusions were made. Platinum was cheaper than gold, harder and more resistant than silver, and infusible at the highest temperatures of our furnaces; it combined the valuable properties of gold with those of porcelain. Without the use of platinum the composition of most of the mineral species would still be unknown."

Since the days when there was only one great teaching laboratory in the world, wonderful strides had been made in chemical experimentation and analysis, and the demand for platinum apparatus had grown enormously. In addition to the myriads of crucibles, of various shapes and sizes, chemists now required a host of other platinum utensils, such as dishes and trays, spatulas, tubes, distilling apparatus, electrodes, &c. As some conspicuous instances of successful experimentation which depended on the use of platinum apparatus, the author mentioned Moissan's great work on the isolation of fluorine, and the proof by Mme. Curie and Mlle. Gleditsch that the action of radium emanation on copper solutions did not produce any lithium, as Ramsay had supposed.

While platinum was less in evidence in the equipment of physical laboratories, it entered into the construction of a great number of apparatus and instruments which were employed in the study of heat, electricity, spectroscopy and the recently-discovered radiations. Much of this apparatus was made of glass, and in providing it with attachments of platinum wire and plates advantage was taken of the fact that platinum and glass expanded and contracted at the same rate. The coefficient of expansion of platinum was also utilised in the Breguet thermometer. The nozzles of the oxyhydrogen and the oxyacetylene blowpipes which were used for cutting iron and steel, as well as for fusing platinum, quartz, and other highly refractory materials, were often made of platinum.

In the manufacture of sulphuric acid, both by the leaden chamber and the contact processes, the metal was used in very large quantities. Since Johnson & Matthey constructed their first platinum still in 1809, this old firm and other manufacturers had furnished a great number of such retorts, and of much greater capacity, to sulphuric acid works in all parts of the world. In the newer contact process, as well as in other chemical manufactures which depended on catalytic action, platinum sponge or platinised asbestos were largely used as the "contact materials." Enormous quantities of platinum also were consumed in the manufacture of electrical appliances, especially of incandescent lamps and the sparking points for internal-combustion engines. But, impressive as were the quantities of platinum required for the purposes mentioned, they were equalled, if not exceeded, by those which were absorbed in the manufacture of dental supplies. It was estimated that fully 50 per cent. of the platinum of commerce was consumed in the production of pins, sockets, and other attachments of artificial teeth. For many years parts of jewellery had been made of platinum, on account of the pleasing contrast of its colour with the various shades of gold; but it was only in recent years that the beauty of the metal had come to be fully appreciated. At the present time the greater part of the more elaborate settings of diamonds and pearls, as well as a great number of other articles of jewellery, were made of this material.

Just as gold and silver were alloyed with copper (and other metals) to increase their hardness and wearing qualities, so platinum was often alloyed with iridium to increase its resistance to abrasion and the attack of chemicals. Such an alloy was termed "hard" platinum, as distinguished from ordinary platinum. It was more expensive than the latter. Thus most of the vessels used by chemists contained about 2 per cent. of iridium, while much larger proportions of the latter—from 10 to 15 per cent.—were added to the platinum used for the construction of standards of length and weight, for electrodes exposed to severe chemical attack, for sparking plugs, and the points of fountain pens. For special purposes platinum was sometimes alloyed with other metals. An alloy with rhodium was used in certain electric pyrometers; and various alloys with copper, nickel, tungsten, and manganese served as substitutes for steel in the construction of non-magnetic watches. Of the compounds of platinum, only a few had found application in analytical chemistry, photography, and physics. The most important, platinum chloride, or rather chloro-platinic acid, was an invaluable reagent; and barium platino-cyanide was used on account of its fluorescence, which converted the ultra-voilet rays and X-rays into visible radiations. The shadows made by X-rays were best projected on screens coated with this salt.

In view of the great increase in the price of platinum, it was but natural that many and persistent attempts had been made to find substitutes for it. In a few instances this had been partially, or even wholly, accomplished; as yet, however, the introduction of such substitutes had no appreciable effect upon the price of the metal; indeed, it might be said that the demand for platinum had steadily increased in spite of them. Among the substitutes, the author mentioned platinum-clad nickel steel wire, which was beginning to displace the solid wire in incandescent electric lamps; wires of nickel alloys which were used in making the cheaper grades of artificial teeth; asbestos threads which had replaced platinum wire in the Welsbach mantles; and the fused-quartz wire, now so extensively employed in chemical laboratories in the place of platinum utensils.

The Oil Motor Vessel "Jutlandia."—The motor vessel "Jutlandia," built by Messrs. Barclay, Curle, & Co., Whiteinch, for the East Asiatic Company, of Copenhagen, has recently completed a long and very successful voyage from Genoa to Singapore in 25 days, during which time the Diesel motors worked steadily and well, and propelled the ship at an average speed of 11 knots. The fuel consumption, including that of the auxiliaries, was 8·9 tons of oil per day, as compared with the 38 tons of coal per day which would have been required to do the same work on a steam-driven vessel.

THE WEARING QUALITIES OF BRONZES.

IN a paper presented before the sixth congress of the International Association for Testing Materials, A. Portevin and E. Nusbaumer gave the results of an investigation conducted to determine the influence of chemical composition on the wear of bronzes. Electrolytic copper and commercially pure tin were melted and alloyed in various proportions in plumbago crucibles, and the metal was cast into test bars in sand moulds, and from the test bars specimens were taken and tested by means of an abrasive mill. The principle of this apparatus was based upon the determination of the friction between the specimen and the circumference of a polished wheel revolving at high speed in an oil bath. A lever bore against the specimen with the pressure of a known weight, and as this lever descended in accordance with the wear of the specimen, the latter factor could be determined with the aid of a micrometer screw. The speed of the wheel of the machine was always 3,200 revolutions per minute, and each test was continued for 2,000,000 turns. To lubricate the friction wheel a high grade automobile oil was used. The analyses of the alloys tested are given in the accompanying table.

Analysis of Alloys Tested.

Copper, per cent.	Tin. per cent.	Phosphorus, per cent.	Lead, per cent.	Iron, per cent.	Zinc, per cent.
91·12	5·73	...	0·12	0·15	2·68
88·31	8·78	...	trace	0·31	2·40
84·45	13·89	...	0·23	0·04	1·22
80·22	19·16	...	trace	0·13	0·43
94·80	5·08	0·011	...	...	...
89·54	10·02	0·012	...	0·05	0·21
85·45	14·42	0·015	...	0·05	trace
80·11	19·79	0·020	...	0·08	trace

The results of the tests showed that the bronzes containing no phosphorus improved in wearing qualities with increased tin percentages up to 10, above which the wear became considerable, the influence of the tin being particularly injurious in cases where strong pressure was applied. The introduction of phosphorus, it was found, produced a rather curious effect. While the phosphorised bronzes of low tin content were worn rather more than the non-phosphorised bronzes of the same composition, phosphorised bronzes containing more than 10 per cent. tin were decidedly less subject to abrasion than the corresponding non-phosphorised bronzes.

The introduction of phosphorus, therefore, produced an average bronze in which relatively considerable variations in the tin content were not accompanied by more than rather feeble variations in the corresponding wear, although the wear remained proportionate to the content of tin. In the course of the experiments a very interesting phenomenon came to light in the case of certain of the bronzes. It was noted that the wear after being normal at first, suddenly strikingly diminished, dropping almost to zero at a very rapid rate, and the experiment being carried further than usual, after three or four million turns, the specimen would suddenly give way and wear away with great rapidity, and after considerable investigation the cause of this curious effect was found to consist in the formation of a skin of cold worked bronze, which resisted wear until it was cut through when the wear became extremely rapid.

The Increasing Demand for Petrol.—It has been generally stated, says "The Motor," that the price of petrol will rise even higher in the near future, and this for no other reason than that the demand is increasing. This will be a serious thing for the motor industry. The Petrol Committee of the R.A.C. are moving in the direction of discovering an alternative fuel, but their efforts in this direction cannot immediately affect the situation if they do so at all. The matter is of such vital importance as to call for more immediate results than the Petrol Committee of the R.A.C. seem likely to evolve from their protracted sittings. Government intervention has been suggested, but it is doubtful if the magnates would be even slightly concerned if such intervention were threatened. They control a foreign commodity, and they say they can get their price elsewhere if not here. Our contemporary suggests international intervention, and considers that the International Union of Motor Manufacturers is the most suitable body to undertake the work.

MISCELLANEA.

A 2,000-b.h.p. Single-cylinder Diesel Engine.—According to our contemporary, "The Motor Ship," a complete 2,000 b.h.p. single-cylinder Diesel engine has recently been completed at the works of Messrs. Krupp. As much as 2,500 b.h.p has, it is stated, been developed in its single cylinder, which is of the two-cycle double-acting type.

The Melting Point of Tantalum.— A new determination of the melting point of tantalum has been made by Pirani and Meyer and reported in a recent communication to the Deutsche Physikalische Gesellschaft. The value found is 2,850° C., which is closer to the previous measurement of the same experimenters than was expected, as the latter was supposed to involve serious errors.

The New British Submarines.—The two vessels of the E class which have just been launched on the Medway are, it is stated, four times the size and have four times the propelling power of the earlier A's. Their surface speed is four knots faster, and their submerged speed three knots faster. Of the F class, several of which are expected to be completed before March 31st, it is said that their propelling engines will be of 5,000 h.p., which will give them a surface speed of 20 knots and a submerged speed of 12 knots.

New North British Locomotives.— Two examples of a new type of express passenger bogie locomotive have recently been completed in the North British Railway Company's workshops. Superheating, which is comparatively new in its application to locomotives in this country, has been adopted. The length over all of engine and tender is 56ft., and the weight with full running equipment 103¼ tons. The engines are intended for the Waverley route.

Electricity Supply.—Mr. S. D. Schofield, in his address delivered at the opening meeting of the new session of the Leeds Section of the Institution of Electrical Engineers, said that one of the main points to be considered in the future would be the fixing of standard pressures and periodicities, and engineers interested in the manufacture of motors or incandescent lamps well knew what a boon this would be to them. The day of small supply stations was passing away, and if electrical energy was to be universally adopted for industrial purposes, at prices which would be profitable alike for the producer and the consumer, it could only be done with large generating units at stations where fuel could be obtained easily and cheaply, and where an abundant supply of water for condensing purposes was available. Generating stations which were put down to supply direct current, and for economic reasons were necessarily in the centre of a given area, would be dismantled and utilised as sub-stations, taking current in bulk from a large central station. The question as to whether these large stations would be controlled by companies or by groups of local authorities would settle itself in the future.

"Wireless" Compasses.— At a meeting of the Institution of Engineers and Shipbuilders in Scotland, held at Glasgow, a paper on "The Determination of a Ship's Position at Sea by Wireless" was read by Mr. J. Erskine Murray, D.Sc. Dr. Murray referred at length to two electrical methods which were at present in use. The Bellini-Tosi wireless compass, if fitted on board a ship, enabled the navigator, he said, to determine the bearing of any ordinary station on sea or land, while the Telefunken compass made possible the determination of the bearing of any land station fitted with the special apparatus, even though the ship station was of the ordinary type, without special fittings. In the latter case, however, the ship was unable to determine the bearing of an ordinary wireless station. There were advantages in both systems, and the choice of one or the other would be decided largely by the nature of the apparatus at the coast stations with which the ship was most frequently in communication. In the Bellini-Tosi compass the direction of the incoming waves from the distant station was determined by observations on board the ship. In the Telefunken system a series of signals were sent out from the shore station, following each other at fixed intervals of time, and in directions which corresponded successively to each point of the compass. What the operator on board ship had to do in order to determine the bearing of the land station was to note which signal was the weakest. Wireless now provided a simple

means of obtaining knowledge of bearings, knowledge which it had been difficult—in some cases impossible—to obtain by the navigational methods hitherto used.

North-east Coast Institution of Engineers and Shipbuilders.—The new president of the North-east Coast Institution of Engineers and Shipbuilders (the Hon. Sir C. A. Parsons, K.C.B.) and the Hon. Lady Parsons held a reception at Newcastle on the 22nd ult. The function was a pleasing social success. A feature of the gathering was a number of interesting models which were on view. These included what is perhaps the largest and most expensive ship model in the world, viz., that of the Brazilian battle-ship "Minas Geraes," which was built by Sir W. G. Armstrong, Whitworth, & Co. at Elswick in 1908. Then there was a gyrostat lent by Messrs. Wm. Denny & Bros., designed and invented by the late Mr. Beauchamp Tower for the purpose of obtaining a steady platform at sea. Demonstrations were given of the Frahm tank for reducing the rolling of ships, which is owned by the Parsons Foreign Patents Company, Ltd. The model shown was freely suspended from a point corresponding to the metacentre of the ship, and oscillated similarly to a pendulum. The action of the auto-rolling device was seen at once by simply opening or closing certain air valves. This auto-rolling tank has already been fitted to 30 steamers, of a total displacement of 624,200 tons. Another device for reducing the rolling of ships was the Schlick gyroscope, which is designed and constructed by Messrs. Swan, Hunter, & Wigham Richardson, Ltd. A propeller working in water illustrating cavitation was shown by the Parsons Marine Steam Turbine Company, as were models of the helical gearing as adopted in geared turbine installations, the turbine machinery of H.M.S. "Viper," and of a wheel showing turbine blading.

Scottish Water Power.—In the course of his inaugural address, delivered at the opening meeting of the Scottish Local Section of the Institution of Electrical Engineers, held in Glasgow, Mr. William M'Whirter said the recent coal strike had shown the possibilities underlying a public supply of electrical energy, and what could be done in such emergencies if proper precautions were taken, and if a sufficient supply of fuel were in stock. Towards this end it would be necessary to give increasing consideration to the sites of power stations, and it would be found expedient, he thought, to locate these right on the coalfields, provided condensing water was also available in abundance. It would be cheaper to transmit the electricity than to carry the coal to the power stations. At the same time, they were faced with the fact that the amount of available coal fuel was limited, and they would require to see that sources of power were tapped which had hitherto been neglected. From Fort William to Fort Augustus the chain of lochs forming the Caledonian Canal might be utilised in order to give a supply of power in excess of anything at present known. The level of Loch Lochy was 93ft. above the sea. The loch was 10 miles long, and of an average breadth of one mile. Its level might be raised to a height of 150ft., which would double its storage capacity, and also connect it with Loch Arkaig. With the present knowledge of high-tension electrical power distribution it would be possible to bring supplies of current from such a district to Glasgow and the West of Scotland, the distance being not more than 100 miles, and the route nearly all through country where there would be no difficulty in obtaining the necessary wayleaves. Mr. M'Whirter referred also to Loch Ness as being available for similar purposes.

Porous Metals for Bearings.—A writer in "Comptes Rendus" gives a method of making porous metals which can be used for bearings, packing, or accumulator plates. He gives a case of this nature in which he allowed an alloy of 50 per cent. of antimony and 50 per cent. of lead to cool to below 450° C. At this temperature the antimony begins to crystallise out. The mass was then subjected to centrifugal motion and the liquid eutectic, which does not finally solidify until a temperature of 225° is reached, and which then contains 87 per cent. of lead. A tin and lead alloy was made and treated in the same manner. The alloy contained 20 per cent. of lead. It was suggested by the author that such metals might be used to form semi-metallic alloys by filling the pores with fats, resins, or enamels; while by the inclusion of lead oxide in the case of porous lead, accumulator plates could be produced.

INDUSTRIAL AND TRADE NOTES.

Steel Works for New South Wales. — The Government has approved of the undertaking to reserve an area of land and a private railway and to dredge a portion of the Hunter River to facilitate the establishment by the Broken Hill Proprietary Company of iron and steel works at Newcastle. The works will, it is said, cost about two millions sterling.

Midland Iron Trade.—Further evidence of the iron trade boom is afforded by the bi-monthly return for September and October just issued by the Midland Iron and Steel Wages Board. According to this the average net selling price of manufactured iron has been £7. 17s. 7d., or an improvement of 7s. 3d. upon the preceding return. Wages will be advanced 5 per cent. The total new puddling rate becomes 10s. 9d.

The Use of Suction Gas Plants in South Africa. —The "Agricultural Journal of the Union of South Africa" states, in a recent issue, that although suction gas plant and engines are at present extensively employed by farmers in South Africa for pumping water for irrigation, they should also, on account of the low cost of working, be more widely used for other purposes such as for grinding mealies, cutting chaff and ensilage, &c.

Electrification of London Railways. —The London and South-western Railway Company will, it is reported, begin the electrification of the routes near London early next year. It is expected that the work will take about two years to complete. The first line to be electrified will be the loop line from Waterloo to Kingston and back, viâ Wimbledon, Richmond, and Putney. The Hounslow loop and the Shepperton and the Hampton Court lines will be electrified afterwards.

Australian Turbine Steamer.—Messrs. William Denny & Bros., Dumbarton, launched a few days ago the turbine steamer "Wahine," which they have built for the Union Steamship Company of New Zealand. The vessel is designed for service between Wellington and Lyttleton, and she is similar generally to the "Maori," which was built at Dumbarton in 1907. The principal dimensions are: Length, 374ft.; breadth, 52ft.; and depth, 27ft. 6in. The propelling machinery consists of three sets of turbines supplied with steam from water-tube boilers of the Babcock & Wilcox type.

Trials of a Diesel-engined Steamer. — The Diesel engine-driven tank-ship "Juno," built by the Nederlandsche Scheepsbouw Maatschapij, of Amsterdam, and engined by the Nederlandsche Fabriek van Werktuigen en Spoorweg-Materieel, also of Amsterdam, has successfully completed her trials in the North Sea. This vessel, which has been built to the order of the Anglo-Saxon Petroleum Company, of London, is of the following dimensions: 258ft. long by 43ft. beam, with 20ft. moulded depth, and 18ft. draught, on a dead-weight capacity of 2,450 tons, and the engines, which are of the Werkspoor-Diesel design, of 1,100 b.h.p., are of the four-stroke cycle type, having six cylinders.

Clyde Shipbuilding. — Clyde shipbuilders have launched 29 vessels, aggregating over 68,488 tons, during November, bringing the total for the eleven months up to 588,806 tons. This exceeds the previous highest for the same period by 50,000 tons. Only on three occasions has this total been exceeded by the total year's output, so that a record for the year seems assured. Included among the new contracts placed in November are three battleships of 27,000 tons each for the British Government, a large twin-screw passenger steamer for the Cunard Company, three oil-engined Atlantic Transport liners, an oil tank steamer of 10,000 tons, and two steamers of 8,400 tons carrying capacity for the Clan Line.

Large Direct-current Generators. — The largest direct-current generators yet designed are being built by the General Electric Company, of Schenectady, N.Y., for the plant of the Southern Aluminium Company at Whitney, N.C. Here seven vertical waterwheel units will each drive a 5,000 kw., 20,000 amp. 250-volt, 170 revs. per minute generator. They will weigh about 150 tons, and will be 22ft. in diameter, with a height of 13ft. above the floor. The entire rotating element of the generators will be supported from an overhead bearing. The units are designed for safety at a runaway speed 75 per cent. above normal. Wheel governors will be provided with remote electric controls for hand and automatic operation.

A New Alpine Railway.—The Lotschberg Alpine Railway is approaching completion. The line, which is 48 miles in length, and has occupied more than six years in building, starts at Spiez, on the Lake of Thun, and finishes at Brigue, in the Rhone Valley, where it connects with the Simplon. The line forms a short cut to Italy, and will enable travellers to save from one to five hours on the journey, the wide detour formerly necessary in

order to reach the Simplon being obviated. Not only was it necessary to pierce the Bernese Alps in order to construct this direct route, but numerous wide ravines had to be crossed by means of steel bridges and granite viaducts, and embankments to be constructed along the edge of lofty precipices. Electric locomotives of large power have been specially designed and constructed for use on the new line.

Granting of Certificates under the Coal Mines Act. — The Home Secretary gives notice that he has approved the following institutions for the purpose of granting certificates under his Order, dated February 27th, 1912, prescribing the qualifications of surveyors for the purpose of sections 20 and 21 of the Coal Mines Act, 1911: City and Guilds of London Institute, Royal School of Mines, Wigan and District Mining and Technical College, University of Birmingham, University College, Nottingham. Examinations for surveyors' certificates are also held by the Board for Mining Examinations in May and November in each year at the following centres: Edinburgh, Newcastle-on-Tyne, Sheffield, Wigan, Cardiff, and Birmingham. All applications for information should be addressed to the approved institutions, or, in the case of the Board for Mining Examinations, to the Secretary of the Board, Home Office, London, S.W.

British Trade during 1911. — Detailed information of the trade between the United Kingdom and each foreign country and British Possessions during 1911 is contained in a Blue Book just published. It is stated that of the total imports in the year, goods to the value of £508,897,796 were consigned from foreign countries and £171,259,731 from British Possessions and Protectorates. Of our total exports, £295,275,154 was the value of consignments to foreign countries and £158,844,144 of consignments to other parts of the Empire. Comparative tables for the years 1907 to 1911 show that, as compared with the first-mentioned boom year, imports from foreign countries increased by £20,033,952 (or 4 per cent.), and those from the Empire by £14,315,633 (or 9 per cent.). Exports to foreign countries rose £8,688,238 (or 3 per cent.) and to the Empire £19,395,977 (or 14 per cent.). Of our imports, Germany sent £65,280,739; Russia, £43,154,411; and the United States, £122,694,486; while British India was represented by £45,423,316 and Australia by £39,096,097. Of our exports, Germany took £29,283,683, the United States £27,519,356, Australia £30,881,094, and India £52,245,664.

North of England Iron Trade.— The accountants report to the Board of Conciliation in the northern iron trade states that during September and October the output of rails, plates bars, and angles was 13,484 tons, and the average net selling price £6. 19s. 7·03d. per ton. In the preceding two months the output was 12,229 tons, and the ascertained selling price £6. 16s. 3d., whereas in May and June 12,543 tons were produced, and the price returned at £6. 13s. 0·84d. Of the output bars form 83·37 of the whole, the tonnage being 11,242 tons. The report shows that since the second half of last year set in there has been better trade in all departments. The output is the largest known for some time past, and the ascertained price is the best since 1907, which itself was a boom year in the iron trade. Already this year the total output is 53,955 tons, and the next best was 1907, which for the full twelve months was 67,312 tons. There is every reason to believe that the present improvement will continue, for the ironmasters on all hands report full order books. Ironworkers' wages are ruled by a sliding-scale based on the return, and in accordance with that scale there will be an advance of 3d. per ton on puddling and 2½ per cent. on all other forge and mill wages, to take effect from Monday last.

The Trade of Russia.— In his report on the foreign commerce of Russia and trade of the Consular district of St. Petersburg for the year 1911, the British Consul remarks that the prosperity of Russia, so marked in 1910, continued well into the year under review. The number of industrial establishments, registered at 15,721 in the beginning of the year, showed an increase of 6·7 per cent., as compared with 1910, and the number of hands employed had grown to 1,952,000, or an increase of 6·5 per cent. The total volume of trade, both exports and imports, again exceeded that of the preceding year, thereby establishing a new record in 1911. The output of coal and anthracite increased by 20 per cent. Prices were very firm throughout the year, and, of course, rose considerably during the past winter owing to the strikes in the United Kingdom. The price of hard fuel was also greatly influenced by that of liquid fuel, which was high, owing to the reduced production of naphtha in the Baku regions, estimated at 650,000 tons short of the actual requirements, besides which the demand for liquid fuel is increasing owing to the widespread use of internal combustion motors for industrial and other purposes. It is estimated, says the Consul, that the aggregate output of naphtha in 1911 was 9,000,000 tons, or some 4·6 per cent. less than in 1910.

Large Cargo Turbine Steamer. — A large cargo turbine steamer, the "Cairnross," was launched from Messrs. Doxford & Son's shipyard at Pallion on the 26th ult., for the Cairn Line of Steamships, Ltd. (Newcastle). The vessel is intended to carry about 7,800 tons deadweight on about 24¾ft. draught. The length of the ship between perpendiculars is 370ft., breadth 51ft., and moulded depth 27ft. 9in. Her estimated speed is 10 knots. The principal point of interest in the ship is the propelling machinery, which is to be on the geared turbine system. She is the first purely cargo steamer actually built specially to take machinery of this type. The system has already been tried in the "Vespasian," whose machinery was converted by Messrs. Parsons from the ordinary triple-expansion type to this latest development of Messrs. Parsons' marine practice. The "Cairnross" will therefore be the first ship built for the application of the system to the purpose for which it was really designed, viz., the application of high speed turbines to the ordinary medium speed and low-speed type of cargo steamer. The installation consists of one high-pressure and one low-pressure turbine, both of which gear by means of double helical steel pinions into a large double-helical spur wheel. All the gearing is machine cut by special machinery at Messrs. Parsons works, and the whole forms a very efficient and silent method of transmission. This system permits of the economy and compactness of the high-speed turbine being taken full advantage of. The results of exact trials of this type of machinery will be looked forward to with considerable interest. The turbines and gearing have been constructed by Messrs. Parsons' Marine Steam Turbine Company, Ltd., at their Wallsend works; whilst the boilers, shafting, and propellers have been constructed by Messrs. Wm. Doxford & Sons, Ltd., the builders of the ship.

The Workmen's Compensation Act and its Burden on Industry.—The Home Office has just issued in the form of a Blue book the statistics of compensation and of proceedings under the Workmen's Compensation Act in 1911. Sir Edward Troup, the permanent secretary at the Home Office, states that returns have again been collected from the seven great groups of industries—mines, quarries, railways, factories, harbours and docks, constructional works, and shipping. These returns furnish materials for a general review of the working of the Compensation Act of 1906 in relation to the main body of the industries of the United Kingdom. In these seven groups of industries the number of employers included in the returns was 139,881, and the aggregate number of persons employed coming within the provisions of the Act was over 7,000,000, of whom more than 5,000,000 come under the heading "factories." In these industries in the year 1911 compensation was paid in 4,021 cases of death and in 419,031 cases of disablement. The average payment in case of death was £154, and in case of disablement £5. 16s. The annual charge for compensation, taking the seven groups of industries together, averaged 8s. 5d per person employed. It was lowest in the case of persons employed in factories, being only 4s. 6d. per person. In the case of railways it rose to 10s. 9d., in quarries to 14s. 3d., and to 13s. 5d. in constructional work. It was highest in docks, 21s. 9d., and in mines 23s. 8d. It is noteworthy in the coal-mining industry, that the charge arising under the Act works out at about 1s. 1d. only per ton of coal raised. The total amount of compensation paid under the Act in the seven groups of industries during the year was £3,056,404, as compared with £2,700,325 in the previous year. When to this is added the costs of management, commission, legal and medical expenses, &c., the total charge borne by the seven industries probably amounts to more than £4,000,000.

The Manufacture of Ferro-alloys.—With regard to the supply of ferro-alloys used in the manufacture of high-grade steels, the "Sheffield Daily Telegraph" states that a British firm who manufacture ferro-tungsten and ferro-molybdenum have met with so much support that they are putting down additional plant to increase their output and to take up the manufacture of other alloys, including ferro-chrome. This English material is claimed to be superior in every respect to that produced abroad and even preferred in many works on the Continent, while the price is as low or lower. With the object of coping with the increased business, the works where these alloys are being made are being acquired by a new limited company, with a capital of £150,000. In the course of the next few months, this company claims that it will be in a position to meet all the British requirements of ferro-tungsten, ferro-molybdenum, ferro-chrome, and ferro-vanadium, as well as such other alloys as may be required.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Method of producing heat, heat-radiating flame, and inflammable gases by fractionate combustion and apparatus therefor. Meeze. 2941.
Chain V-belts. Roberts. 18087.
Solidification of hydrocarbon oils. Armstrong & Mordan. 18300.
Packing for piston-rods. Garratt & Barringer. 19660.
Pneumatic ore stamps. Fraser & Chalmers, Ltd., and Behr. 22083.
Derricks. Farrands. 24991.
Block-signalling apparatus for railways. Bousfield. 24995.
Aerial machines. Goldman. 25024.
Steam meters. Woodroffe & Boultbee. 25112.
Apparatus for measuring and delivering measured quantities of liquid. Holmes. 25115.
Heating of railway carriages. J. Stone & Co., and Darker. 25144.
Piston-traversed ports of reciprocating engines. Wells & Davidson. 25204.
Means for propelling ships. Gounouilhou. 25236.
Aeroplane. Wiles, MacLeod, & Wiles. 25363.
Controlling the supply of liquid or gaseous fuel and air to furnaces. Crosbie. 25410.
Annealing of metallic sheets and appliances used therein. Thomas, Thomas, & Davies. 25520.
Ship construction. Sir W. G. Armstrong, Whitworth, & Co., and Burgess. 25595.
Aerial machines. Meugniot & Meugniot. 25695.
Centrifugal pumps. Kerr & McEwan. 25877.
Hot-air engines. Stockmann. 26260.
Grates for refuse destructors. Leask. 26474.
Self-propelled vehicles or motor wagons. Clayton & Co. (Huddersfield), and Clayton. 26570.
Automatic coupling for railway vehicles. Smith. 26690.
Apparatus for indicating the depth of liquids in and for forcing liquids out from ships' holds. Young & MacDonald. 26989.
Axle-boxes. Lassmann. 28061.
Process for producing peat fuel or coke, and apparatus therefor. Prioleau & Prioleau. 28145.
Vices. Vanes. 28530.
Recording devices for use in instruments for measuring the volume of air or gases. Arndt. 28630.
Pumps. British Thomson-Houston Company. 28738.
Joints or couplings for pipes. Durand. 28982.
Operating producer gas power installations. Hutchins. 29200.

1912.

Recording mechanism for meters. Hall. 249.
Braking means for use in shunting operations on railways. Chatterton. 620.
Gas-producing apparatus. Loehlein. 673.
Apparatus for filtering, cleansing, and purifying water, oil, or other fluids. Hamilton & Wheatley. 813.
Tube expanders. Robinson. 997.
Governors for centrifugal air compressors. British Thomson-Houston Company. 1496.
Machines for making spirally-wound tubing. Beadle. 2152.
Lubricating systems for internal-combustion engines. McCurd. 2539.
Pyrophorous metal alloys. Elektrochemische Werke Ges. 3350.
Automatic couplers for railway carriages and wagons. Willison. 3740.
Gear-cutting machines. Fawcus. 4694.
Chucks and tool shanks for use therewith. Jennings. 4769.
Cut off valves for steam engines. Lees & Lees. 6538.
Manufacture of silicon sheet steel. Connell. 7095.
Valves for internal-combustion engines. Holst. 7111.
Pipe rolling machinery. Schilling. 8594.
Cylindrical grinding machines. Royston. 8703.
Balancing device for flying-machines. Converse. 9479.
Toothed gearing. Dumont. 9852.
Aeroplanes. Sueter, Boothby, & Paterson. 11102.
Automatic car coupling. Passi & Pacona. 11379.
Turbines. Price. 11400.
Adjusting mechanism for grinding mills. Spellman & Twigg. 11458.
Driving belts. Gray. 11499.
Flexible stay bolts for boilers. Stafford. 11606.
Carburetters for internal combustion engines. Heidelmann. 11676.
Steam boilers. Babcock & Wilcox, Ltd. 12004.
Governing the speed of water turbines. Huguenin. 12452.
Condensation of exhaust fluid in steam engines. Schmidt. 12699.
Dust-excluding and oil-retaining devices for axle-boxes. Lassmann. 12943.
Ball-thrust bearings. Bruhl. 13133.
Turbo-pumps or fans. Elling. 14668.
Railway and tramway points. Meldini. 14823.
Apparatus for determining the specific gravity of gases. Dosch. 15787.
Surface-grinding machines. General Composing Company. 17394.
Rotary internal-combustion motor. Vallez. 18174.
Chill moulds. Phillips. 21676.
Two-stroke cycle internal-combustion engines. Royer. 22439.
Gas turbines. Churchill-Shann. 23286.

ELECTRICAL, 1911.

Apparatus for automatically maintaining a uniform load on the prime mover of an alternating-current generating set. Lancashire Dynamo and Motor Company, and Siddeley. 25109.
Overhead systems for transmitting electricity. Paul. 25364.
Electric resistances. Hirst & Brook. 27189.

1912.

Joint for the metallic coverings of insulated electric wires. Whiting. 81.
Incandescent electric lamps. Lowden. 1180.
Induction furnaces. Solomon. 1839.
Electric power transmission apparatus. Macfarlane Engineering Company, and Macfarlane. 2817.
Electric couplings or connectors. Wilkie. 3772.
Electric search lights. Geb. Siemens & Co. 3812.
Intercommunication telephone systems. White & Parsons. 5035.
Brush-holders for magneto machines for electric ignition. Bloxam. 5446.
Apparatus for the electro-deposition of iron. Tischenko. 5851.
Carbon electrode for electric furnaces. Planiawerke Akt.-Ges. fur Kohlenfabrikation. 14267.
Electrical contact plugs for switchboards. Richter. 16144.

METAL QUOTATIONS.

TUESDAY, DECEMBER 3RD.

Aluminium ingot	90/- per cwt.
„ wire, according to sizes, &c. ......from	112/- „
„ sheets „ „ ...... „	120/- „
Antimony ......£39/-/- to	£40/-/- per ton.
Brass, rolled	9⅛d. per lb.
„ tubes (brazed)	11½d.
„ „ (solid drawn)	9¾d.
„ „ wire	9⅛d.
Copper, Standard	£76/15/- per ton.
Iron, Cleveland	67/3 „
„ Scotch	73/3 „
Lead, English	£18/10/- „
„ Foreign (soft)	£18/2/6 „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£7/12/6 per bottle
Silver	29 11/16d. per oz.
Spelter	£26/7/6 per ton.
Tin, block	£228/-/- „
Tin plates	15/4½ „
Zinc sheets (Silesian)	£29/10/- „
„ (Stettin; Vieille Montagne)	£30/5/- „

The Electrification of a Small Group of Collieries.—At the monthly meeting of the West of Scotland Branch of the Association of Mining Electrical Engineers, held at Glasgow, Mr. A. Campbell King read a paper on the above subject, in which he embodied ideas gathered from his experience with and inspection of electrical installations both in Germany and Scotland. The author said it was to be regretted that a fair proportion of electrical accidents happened with coal-cutters. No doubt many of these accidents were due to the human element, and for that reason as well as others he was one of those who thought that compressed air was the ideal motive power for coal-cutting machines. Frankly, he did not think that a coal-cutter was an ideal subject for electrification, because the conditions under which the motor had to work were anything but satisfactory, owing to vibration and dust. Next to compressed air, however, he favoured the direct-current machine as being preferable to the machine of the alternating type.



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Edited by
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Profit Sharing and Co-partnership.

THE subject of profit sharing or co-partnership in one shape or another has been widely discussed during the last few years. Labour discontent and the disagreements between workmen and employers which inevitably spring out of it are largely responsible for this, and are usually most frequent in times of prosperity. This is perhaps hardly to be wondered at, for profits at such periods are more tangible and the reaping of them by employers more patent. The workman forgets the lean years during which profits may have been small or even non-existent and continuous anxiety perhaps the only "reward" the employer has extracted from his business, owing to his inability to divide more than a small proportion of his losses—and often not even that—with wages. His anxiety on this account cannot as a rule be revealed. It has to be borne silently, and with such patience as he can muster. The workman being unconscious of it naturally thinks it does not exist, and strenuously resists any attempt to make him a partner of it. When the fat years come round, profits do undoubtedly tend to rise more rapidly than wages and the disparity between the workmen's and the employers' share more pronounced.

Much of the praise of co-partnership and profit-sharing schemes that appears in the Press emanates from persons who, whatever their reputation for philanthropy and public spirit, have, as a rule, little experience of the economic factors which regulate industrial enterprise and on which success depends. Evidence of this was, we think, clearly shown at a meeting of the Consultative Council of the Labour Co-partnership Association held a few weeks ago. Lords, church dignitaries, and professors figured largely amongst the speakers, but of influential organisers of industry there was but a thin sprinkling, and these were associated in nearly every case with monopoly industries or businesses in which the economic forces with which the general run of enterprises have to contend are

largely absent. We have sincere respect for Earl Grey and Lord Robert Cecil, but we are not aware that either of them, apart from their academic interest in labour questions, have been conspicuously associated with the establishment or working of business concerns, and, while sympathising with their aspirations for harmonious industrial relationships, we may legitimately question their ability to fully realise the complex nature of many of the factors entering into them. Such a consummation as they wish is as strongly desired by the whole of the industrial community. If co-partnership arrangements are rare it is mainly because employers are unable, for economic reasons, to make them sufficiently attractive to the bulk of workmen as to induce them to give up the freedom of contract which rests on the ordinary wage basis for one which requires a much greater permanence of relationship and, if it is to be of any value at all, must take account of losses as well as profits.

Anyone familiar with industrial history will be able to recall numerous schemes which, begun with the best intentions and under the most favourable auspices, have ended in failure. There are a few, it is true, working satisfactorily, but the firms in these cases enjoy better trading advantages than the general run of concerns, while on more than one occasion offers to introduce them have been rejected. Lord Furness' attempt a year or two ago is a case in point, and it will be remembered that the strongest opponents were the officials of trade unions of the men chiefly concerned. The ordinary wage contract is partnership of a sort by which payment is definitely assured, irrespective of the profitableness of the work in hand, while it leaves to the workman a freedom to terminate it at leisure, which he is very loathe to surrender. It may of course be urged that the employer has equal freedom, but this is more apparent than real, as the trade union dictation and strikes against non-union labour have during the last few years only too amply proved. If an employer commits an illegal breach pecuniary punishment can be inflicted, but in how many cases has this followed the "down tools" strikes and wholesale breaking of agreements of the last few years?

There is much misconception in workmen's minds respecting the rewards of capital and those who organise it. The workman in a large establishment sees perhaps an employer or manager—oftener than not it is the latter, in these days of limited companies, and he usually has risen from the ranks — receiving it may be a reward ten times greater than his own, and perchance is filled with envy. What he fails to perceive is that such organisers are comparatively rare, and that his own lot would be much worse without them, while further, if the whole of the manager's salary was divided amongst those he superintends, the individual increases would be trivial. Again, capital is not, as many workmen think, a mysterious entity outside his reach or in the hands of a few. The great majority of even the largest enterprises are collectively owned, and it is possible even for small capitalists to participate. There is nothing to prevent a body of working men running any enterprise they choose if they so desire just as they run a trade union. But if those who complain of the tyranny of capital were to do so they would find it is not so free from responsibilities as they think. Co-partnership, to be of real value, must participate in the losses and anxieties of bad trade, as well as in the profits and advantages of good trade. It is impossible to fix up an arrangement worthy of the name on any other terms.

Much was said at the meeting we refer to about the influence of machinery and the factory system. We should be the last to say that it is perfect, but we deny that it has been retrograde, and those who speak in this strain know least about it. No one who can look back 50 years can pretend for a moment that workmen are not far better off now in every way than they were then. The State has insisted more and more on better conditions of employment, and it is much easier to secure them in big establishments than small ones. Much of the discontent observed springs not from the factory system, but from the higher standards of living now prevalent. Big communities demand light, power, water, transport, and sanitary services of greater efficiency than contented a past generation, and these advantages imply higher rates, rents, and costs of commodities which are ultimately spread more or less over every class of society. These various demands in a measure have outgrown the rate of production, notwithstanding that improvements in machinery have tended to neutralise them, though it may here be pointed out that workmen not infrequently offer the strongest opposition to their introduction, and when to this they couple demands for shorter hours and higher wages it is not difficult to understand why expectations are not realised. Discontent is not a thing to be altogether deplored. It does at anyrate tend to a discussion of social defects and so helps to eliminate pernicious fallacies. We cannot help feeling that much of the present labour dissatisfaction with capital arises from lack of appreciation of the economical principles on which the welfare of both depend, and which may be summed up in the trite adage that "you cannot have your toffy and your halfpenny too." All schemes of industrial co-partnership that we have seen ignore the fact that enterprise is an essential feature of progress and in its initial stages often involves serious risk and great anxiety, while success in any case nearly always depends on the strenuous efforts of a few individuals, and not infrequently never arrives. Profits in the early stages cannot be discussed, for it may be years before they are reaped or they may never come at all. This is a common experience in nearly every branch of industry and the risks involved are only too palpably reflected in any share list. How, in such cases, we would ask, can any system of profit-sharing or co-partnership be instituted or the relationship between employer and workman be more than an ordinary business contract? An interesting light on this aspect of profit-sharing schemes is afforded by a report on Profit-Sharing and Co-partnership just issued by the Labour Department of the Board of Trade, and an abstract of which will be found on another page. From this it appears that out of 299 schemes of this kind which have been tried, no fewer than 163 were abandoned after trial, and in more than half of these, it is stated, "the cause was traceable to a falling off in business and to the fact that there were no profits to share."

Death of Prof. Jamieson.—The death occurred on the 4th inst. at Glasgow, of Prof. Andrew Jamieson, M.Inst.C.E., F.R.S.E., who was well known as the author of a large number of works devoted to electrical and engineering subjects. He was for some years Principal of the Glasgow College of Science and Art. He afterwards carried on the business of a consulting engineer, and was engaged in educational work. He wrote numerous papers upon the laying of submarine cables, and was the author and joint author of a number of works relating to the application of electricity.

Birmingham Association of Mechanical Engineers.—The annual meeting of the Birmingham Association of Mechanical Engineers was held on Saturday last at the Grand Hotel, Mr. C. H. Wall, the retiring president, in the chair. It was reported that the membership was about 400, as compared with 360 last year. Mr. J. W. Hall was elected president. The Council unanimously awarded the diploma for the best paper read before the association during the session to Mr. E. Cecil Poultney, for his contribution on "Some Considerations in the Design of Express Locomotives, with Special Reference to British Practice."

THE GENERATION AND DISTRIBUTION OF PRODUCER GAS IN SOUTH STAFFORDSHIRE.*

BY HERBERT ALFRED HUMPHREY, M.INST.C.E.

The South Staffordshire Mond Gas (Power and Heating) Company is a pioneer undertaking, since it is the first example of a company giving under parliamentary powers a supply of producer gas for public purposes. The advantages of such a supply have now been amply demonstrated, and, in view of the probability of other schemes of a like nature being carried out in the future, precise information and data should prove of interest to the members of the Institution. The Act contains clauses prohibiting the sale of gas for domestic purposes or for illumination, and the limit of carbon monoxide in the gas distributed is fixed at a maximum of 14 per cent. The area of supply comprises 123 square miles, within which there are six corporations, 16 urban district councils, and three rural district councils. For the central station an area of about 40 acres of land, adjacent to railway and canal, was secured at Dudley Port, Tipton, which is practically the centre of gravity of the whole area. The designs of the central station plant and buildings, and the distribution system, were carried out by the author, as consulting engineer to the company, and the contract for the whole of the work was let to The Power Gas Corporation, Ltd.

Generating Station.—The unit of plant adopted was based on a capacity for gasifying 140 tons of coal per day, and consisted of eight Mond gas producers, together with the necessary gas-cooling, cleaning, and compressing plant; plant for the recovery of sulphate of ammonia and tar; and the machinery, comprising steam boilers, circulating pumps, electric generating plant, motors, fans, &c. The first unit erected was started in operation in February, 1905, and at the present time additions are being made which will increase the output by about 80 per cent. A plant furnishing a public supply of gas has to run day and night all the year round without any stoppages, and in describing in detail the parts of the plant the author has mentioned the various arrangements adopted to ensure such a continuous supply. The first supply to the public was commenced in May, 1905, and up to the present date there has not been a single stoppage of the gas supply from the station, the pressure being maintained in the trunk mains throughout the whole period.

The steam boilers are adapted to be either coal fired or gas fired, or to be fired simultaneously by both means, and the special devices employed for this purpose are described. The blowers are steam driven, and, as there is no storage capacity for gas, the speed of the blowers has to be varied to keep pace with the demand. Of the eight Mond producers one is a spare, and each producer is rated at 20 tons of coal per 24 hours, but in meeting the peak of the load the producers have been worked at 50 per cent. above their rated capacity. The gas from the producers passes through a mechanical washer for removing the dust and for cooling and saturating the gas, and then through an acid tower in which a counter-current of acid liquor absorbs the ammonia from the gas, so that when the liquor is subsequently evaporated solid sulphate of ammonia is obtained. The gas then passes through gas-cooling towers, in the first of which hot water is obtained and is used for heating and saturating the blast during the passage of the water through an air-heating tower. The various circulating systems of water are described in the paper, as also are the further means of cleaning the gas before it leaves the plant.

The gas is measured through rotary meters, and the Act authorises the use of such meters in the sale of gas to customers. The clean measured gas passes to the gas compressors, which are of the Riedler type, and are steam driven. Each compressor is capable of compressing 9,400 cub. ft. of gas per minute up to a pressure of 10lbs. per square inch, which requires 430 i.h.p. The initial pressure chosen for distributing the gas is 7lbs. per square inch, but only 5lbs. per square inch is required at present, since the trunk mains are not working to their full capacity. All the exhaust steam from the gas compressors, pumps, and other steam-driven machinery is utilised in heating and saturating the producer blast. There are a number of electric motors for driving different sections of the plant, and the current for these and for lighting the works is obtained from Westinghouse gas engines.

The periods for cleaning the different parts of the plant are given, and show that the majority of the machinery runs about six weeks continuously day and night before being stopped for examination. The acid towers run for two years continuously, and during the seven years of operation it has not been found necessary to change over the gas-cooling and air-heating towers. Methods of preparing the sulphate of ammonia and tar for sale are described.

The control of the pressures throughout the plant, and the safety devices employed, are dealt with, and the three points at which automatic control has been introduced are: (1) At the blowers, to maintain a constant plus pressure on the inlet to the purification fans. (2) At a by-pass between the delivery and suction sides of the compressors, to prevent the formation of a vacuum on the suction side. (3) At the compressors, by utilising a pressure governor so that the speed of the compressors is maintained to keep constant the gas pressure in the delivery mains.

Operating Records and other Data.—Typical analyses of the fuel used are given, and the methods of handling the fuel and ashes are described. Curves have been plotted showing the coal gasified, sulphate of ammonia made, and the tar sold per month for the 30 months from January, 1910, to June, 1912. Other curves give the total gas made and the total gas sold for a period of 18 months, and, in order to show the fluctuations of the gas supply from hour to hour, the meter readings at the central station are plotted in the form of a curve covering a period of one week. At the peak of the load an output of 1 million cubic feet per hour has now been reached, and the plant, which was designed for gasifying 140 tons per day, has reached the rate of 200 tons per day. Curves showing the principal temperatures and pressures throughout the plant have been plotted, and tables showing the calorific value of the gas over long and short periods are given. The Mond producer gas distributed averages over 150 B.Th.U. per cubic foot, and the regularity of the calorific value is remarkable.

Distribution of Gas.—Owing to the fact that considerable portions of the area of supply are subject to subsidence, due to the presence of disused coal mines, and for other reasons, such as cost, number of joints, &c., steel mains were adopted in preference to cast iron. The author mentions his experience on this subject. Special attention is paid to the coating of the steel mains laid underground, to prevent attack due to the acid water which is prevalent in the district. All mains between 36in. and 21in. diam., inclusive, are of the locking-bar type, particulars of which, and of the method of jointing are given. For the smaller mains, welded steel pipes with screwed joints are employed. Up to September, 1912, there were laid 22,666 yards of locking-bar pipes with lead joints, and 29,181 yards of steel pipes with screwed joints, making a total of 29·45 miles. Additional mains are now being laid. Drawings showing the types of pipes, joints, &c., are also given, and the special precautions taken to ensure a continuous supply are mentioned.

Calculations for Flow of the Gas.—The method of calculating the size of mains required and the formulas used are set out in an appendix, and an account is given of some important experiments carried out by the author to ascertain the loss by friction in a long length of trunk mains. For this purpose the trunk main between the central station and Bilston, consisting of 10,254 yards of pipes ranging in size from 36in. to 27in. diam., was used, and air was blown through these pipes in varying quantities and at various pressures. The results obtained are given in tabular form and show the extent to which the presence of a large number of branches, crosses, valves, and other specials serves to increase the frictional losses. Plans of all the mains laid up to date are given, and the more important features of the distribution system are discussed.

Uses of Gas.—The gas supplied to the consumers is used for two purposes, namely, for the production of power in gas engines and for various forms of heating in furnaces, &c. There are at present over 150 gas engines connected with the company's mains, and it is a significant fact that practically every suction producer situated near the mains has been shut down, the owner finding it more advantageous to take a supply from the Mond gas mains. From this cause 45 gas producer

* Abstract of paper read before the Institution of Civil Engineers, December 10th, 1912.

plants have been thrown idle, 20 of these being suction plants, and 25 pressure producer plants.

A schedule of prices under which gas is supplied is given in an appendix, the price varying, according to the quantity taken, from 1½d. to 2¾d., and the present costs of production and distribution of the gas are compared with the estimates given when the Bill was before Parliament. These figures show that the estimated costs of production based on a much larger plant have been practically realised in connection with the first unit installed. The average price received from consumers was, in June, 1912, about 1·75d. per 1,000 cub. ft., and this is equivalent, having regard to its calorific value, to lighting gas at 7d. per 1,000 cub. ft., so that the benefits derived by the consumers are obvious. They are further illustrated by some actual examples of saving due to the use of the gas.

A list of the heating operations for which the gas is used is given, and additional uses for the gas are constantly being found. Temperatures up to 1,600° C. are being regularly maintained, and the use of gas for heating operations has proved very satisfactory, the constancy in the calorific value of the gas enabling results to be repeated with certainty. Also, there being no stand-by losses and no fuel and ashes to be dealt with, there is realised additional economy and cleanliness.

It is probable that the success which has attended the supply of a cheap fuel gas in South Staffordshire will direct attention to this important subject and will serve to demonstrate the advantages which could be derived by other industrial areas from a similar supply. The subject has been removed from the experimental stage, and the safety and convenience of such a supply has been amply proved. For the year 1911 there was a gross trading profit of £8,856, and it is expected that when the new plant, now in course of erection, is brought into use, the financial results will be greatly improved.

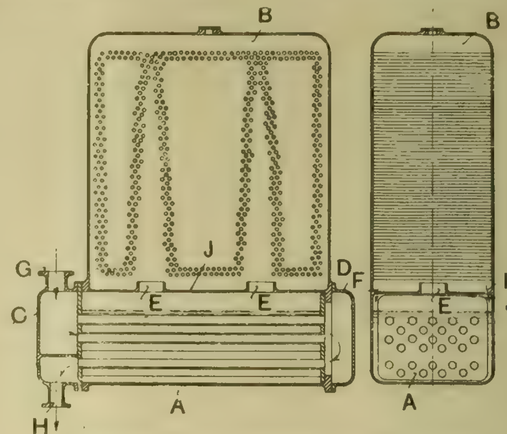
CONDENSER FOR STEAM-PROPELLED VEHICLES.

In steam engines of the type used for vehicles the exhaust steam is usually passed to a condenser in which it is condensed by contact with air-cooled surfaces. The cooling surfaces of such condensers become rapidly coated by an oily deposit from the oil contained in the exhaust steam, and in consequence the efficiency of the condenser is reduced. As these surfaces require to be of very large area owing to the inefficient transmission of heat from steam to air, and as in order to economise space these surfaces must be arranged in the smallest possible bulk, cleaning of the surfaces is for this reason rendered difficult.

To obviate this disadvantage Dr. Wilhelm Schmidt, 2, Rolandstrasse, Cassel-Wilhelmshohe, Germany, has designed and patented the arrangement illustrated, in which the exhaust from the engine evaporates water through heat-transmitting surfaces, such as tubes, the evaporated fluid being thereafter condensed in an air-cooled device and returned to be re-evaporated. The condenser-evaporator, which receives its heat from the exhaust is of comparatively small dimensions, as heat may be efficiently transmitted from steam to boiling water. Further, any oil deposited by the exhaust steam on the heating surfaces of this generator may be easily removed. Cleaning of the complicated air-cooling device is also no longer necessary, as the surfaces of the same are now in contact only with the substantially chemically pure steam from the condenser-evaporator. The condensed exhaust steam may also be used as feed water for the main generator, which supplies the working fluid for the engine. Since this condensed water is at boiling temperature when it is used as feed water for the main generator, a large part of the heat of the liquid is recovered, while the amount of water required by the condenser-generator is exceptionally small and only requires to be renewed at long intervals, thus rendering the arrangement especially suitable for steam engines, for vehicles, and airships. It is also suitable for engines used for other purposes and may be employed in localities where water is scarce.

It is preferable to maintain a pressure of one atmosphere in the condenser-generator, in which case the engine must then work with a back pressure of more than one atmosphere and will thus be attended by a certain loss in power. The arrangement is thus adapted mainly for use with engines in which the power will not be appreciably affected by the high back pressure, *i.e.*, engines operated with steam of very high pressure, say, 20 atmospheres and above. If a pressure of less than one atmosphere is maintained in the condenser-generator, there will be substantially no increased back pressure in the engine.

Referring to the illustrations, there is provided a condenser-generator A, and an air-cooling apparatus B, in operative relationship therewith. The condenser-generator A is



CONDENSER FOR STEAM-PROPELLED VEHICLES.

constructed as a tubular boiler and is provided at its ends with chambers C and D for guiding the exhaust steam through the tubes. The end of the chamber D is adapted to be easily removed in order to enable the heating tubes to be cleaned. Between the condenser-generator A and the cooling apparatus B a partition J is arranged, having two large central openings E and numerous small lateral openings F. The exhaust steam from the engine enters into the chamber C, through the pipe connection G, and flows along the path indicated by the arrows, being thereafter discharged as condensed water through the pipe H. The steam generated in the condenser-generator A rises through the openings E and is condensed on the surfaces of the air-cooling apparatus B, after which it returns as water through the openings F to the condenser-generator.

INSTITUTE OF MARINE ENGINEERS.

At the Institute of Marine Engineers, Stratford, London, E., on Monday, December 2nd, Mr. A. E. Battle gave the concluding part of his lecture on "Wave Motion and Modern Developments in High-frequency Electricity." The principal part of the evening was occupied with demonstrations and experiments illustrating the lecture given by Mr. Battle at the Non-ferrous Metals Exhibition in June. In alluding to wave formation in water, he pointed out that the speed of such waves increased with an increase in depth, also that they could be reflected and refracted in a manner similar to light waves. Converging waves neutralised each other, and no wave effect resulted. Wave motion in ether, he said, obeyed similar laws. With two closed circuits—one connected to a battery of Leyden jars charged from an induction coil, and the other fitted with a glow lamp—the lecturer showed that when electrical oscillations were produced in the primary circuit, parallel oscillations were produced in the secondary circuit of sufficient strength to light the glow lamp. To obtain the best effects from all such conditions it was necessary that the two circuits should be synchronised or tuned to each other, and it was in this direction that researches were made, resulting in the perfecting of wireless telegraphy apparatus. The existence of ether waves was shown by means of a Hertz oscillator and resonator. Wave formation in wires was also demonstrated by means of a long coil of insulated wire connected up to an induction coil, together with a capacity and inductance. By a little adjustment the nodes and antinodes of potential could be traced by means of a vacuum tube. A demonstration of wireless telegraphy was given, and other demonstrations included the dissipation of smoke by electrical means, Röntgen rays, the effects of discharging high-frequency currents into a vacuum, &c.

THE MODERN GAS ENGINE.*

BY A. VENNELL COSTER.

WE are here to-night to consider the modern gas or internal-combustion engine, and the developments which have led up to its present state as a piece of perfect mechanism comparable with the steam engine. It will be interesting also to examine many fuels, ordinary and extraordinary, some of them waste materials, which, in the gas engine, are turned to useful account; as well as the thermal, mechanical and running efficiencies which have made the gas engine equal to all duties imposed upon it in every industry and manufacture throughout the world. In the short time at our disposal, we can only make a general survey of its extended field of action, but concerning important and recent developments in its construction, we may with advantage make a more leisurely and minute examination. By this means, we may hope to obtain a clear conception of some of the reasons that have led to its almost universal adoption. Having the honour to represent the great firm that first introduced the commercial Otto cycle gas engine in this country, you must pardon me, if, speaking of the things best known to me, I dwell too closely upon the "Crossley" engine. We are compelled, in order to attempt perfection, all of us, to specialise in our particular profession or business, and in my desire to give you of my best to-night, naturally it must be derived from the source best known to me by long and daily experience, both in the experimental and finished stages of gas engine manufacture.

In the first place, attention may be concentrated on the internal problems of heat and work within the gas engine cylinder, and see how modern scientists have advanced towards fuller knowledge of the possibilities of this prime mover. Owing to the far-reaching investigations carried out by many modern and learned scientists and chemists, we possess a much clearer grasp of the laws of combustion, and the processes by which heat is turned into work within the internal-combustion engine cylinder. Many of these investigations are now published, and in a very remarkable degree corroborate the deductions arrived at by gas engine manufacturers, who are familiar with the facts of gas engine operations. Many complex conditions, the result of combustion and heat transmission, still awaits solution. But we do know something of the wonderful phenomena hidden within the cylinder, and I will deal briefly with a few of their most interesting phases. The extraordinary thermal advantage of the gas engine over the steam engine lies in the fact that the fuel combustion actually takes place within the engine cylinder. High temperatures are evolved instantaneously by which the power charge under compression is raised to high pressures, and then expands during the power stroke. Of necessity, a certain percentage of the heat is lost through the cylinder walls, and therefore it is the constant aim of the engineer that its cycle should be performed in such a manner as to expose its working fluid to the least possible cooling surface, and that the exposure should be for the shortest time possible, and also that the mean temperature during exposure should be as low as possible.

Experience has definitely taught us that it is practically impossible to maintain in the gas engine the theoretical and ideal spherical form of combustion chamber, comprising a hemispherical compression space and concave piston body, because the most economical ratio between cylinder diameter and piston stroke precludes this form; but the wanton increase of cooling surface resulting in excessively long or irregular pockets or recesses to accommodate the necessary valves and ignition gear, which has been adopted by some makers, is, in my opinion, an unnecessary sacrifice of economy, and an exhibition of laxity in the first principles of design. Then also, a time limit must be imposed upon inflammation and expansion of the gases. A rapidly moving piston assists in creating eddying currents throughout the burning gases, thereby intensifying not only a through mixing of the gases and rapidity of combustion, but reducing the relative importance of conduction losses through the cylinder walls, and assisting in maintaining a higher pressure throughout the power stroke. Although high compression tends to a better combustion of the explosive charge, in practice it is not advisable to approach within the region of temperatures in which spontaneous explosion might result.

It is well known that the curve of expansion lies above the adiabatic curve, which proves that, although the ignition may appear instantaneous, after-burning invariably takes place and the causes of this after-burning are now being carefully investigated. The fact that on the opening of the exhaust valve flames are projected into the exhaust pipe (and this any investigator can very readily see for himself), shows that although the combustion and ignition of the power charge may be as perfect as it can be, still the fact remains that instantaneous combustion does not take place, but that through the whole course of the power stroke the gases are still burning to some extent and creating additional heat, raising the expansion curve on the indicator diagram, and continuing to burn after the opening of the exhaust valve. This after-burning, therefore, adds to the loss of thermal efficiency.

The question may be asked, Is it not possible for complete combustion to take place? Possibly one of the difficulties to be faced is that the specific heat of the combustible gases varies with their compression and expansion, and that at high pressures and temperatures the gases are restrained to some extent from perfect combustion until the lower stage of pressure and temperature is reached. This may account for some portion of the after-burning difficulty. Another reason may be due to the comparative coolness of the cylinder walls. The higher the temperature of the cylinder walls, so the thermal efficiency of the engine increases. It may, therefore, be assumed that the coolness of the cylinder walls prevents the instantaneous ignition of the gases in their proximity, but as the pressure in the cylinder decreases during the power stroke, this envelope of unburnt gases expands and extends into the main volume of the incandescent gases and thereby gets away from the influence of the cylinder walls, and takes its share in the combustion that is in progress, thus adding to the power area shown on the indicator card. Now this delay in the burning of the gases adjacent to the cylinder walls may be considered as of value in preseving the oil film necessary for the lubrication of the piston. You are no doubt aware, that the initial temperature of the explosion may be about 3,000° Fah., dropping to about 1,600° Fah. at the opening of the exhaust valve, and that no lubricant can possibly withstand these high temperatures. Carbonisation of the oil usually takes place at a temperature of, say, 500° Fah., so that some extraordinary conditions must exist to preserve the oil film, and we think we are justified in assuming that the coolness of the cylinder walls, due to the water jacket, and the gas next to the walls being restrained from active combustion, together assist in maintaining efficient lubrication.

It has already been demonstrated that a point can be reached in compression at which gases will ignite spontaneously, due to their high temperatures. This point is about 200lbs. pressure per square inch for producer gas and 190lbs. pressure for town's gas, and it is therefore wise to keep well below these figures, so as to ensure reliable and steady running. One more point before leaving the problem of thermal efficiency. The losses due to after-burning, with its subsequent loss down the exhaust pipe, may sometimes be utilised for external purposes where hot water or steam may be required. Special boilers can be obtained for hot water or steam raising, the hot exhaust gases, as a rule, being made to pass through tubes within a boiler. Assuming 3,000 to 3,600 B.T.U. per brake horse-power, developed by the engine where available for the production of steam, an output of about 2lbs. of steam at 70lbs. to 80lbs. pressure per square inch per brake horse-power developed, could be obtained as a maximum with the engine on a full load factor. Added to this ·65lb. of steam per brake horse-power hour can be obtained from the heat given into the engine jacket water which should be arranged to feed the boiler, which should be fixed as near as possible to the engine to prevent intermediate conduction losses. Such a boiler also acts as a very efficient exhaust silencer.

Now, the modern gas engine is the culmination of over 35 years' experience; splendid work has been accomplished in translating into practical shape the theoretical cycle em-

* Lecture delivered before the Nottingham Engineering Society, November 19th, 1912.

bodied in the early Otto patents and from them the gradual development of the commercial gas engine. This development also was being simultaneously carried out in Germany by the Otto Deutz Company, under the same patent rights. Since the original patents lapsed, dozens of firms have sprung into existence, all competing more or less with the founders of the industry. Competition has, as is usual,

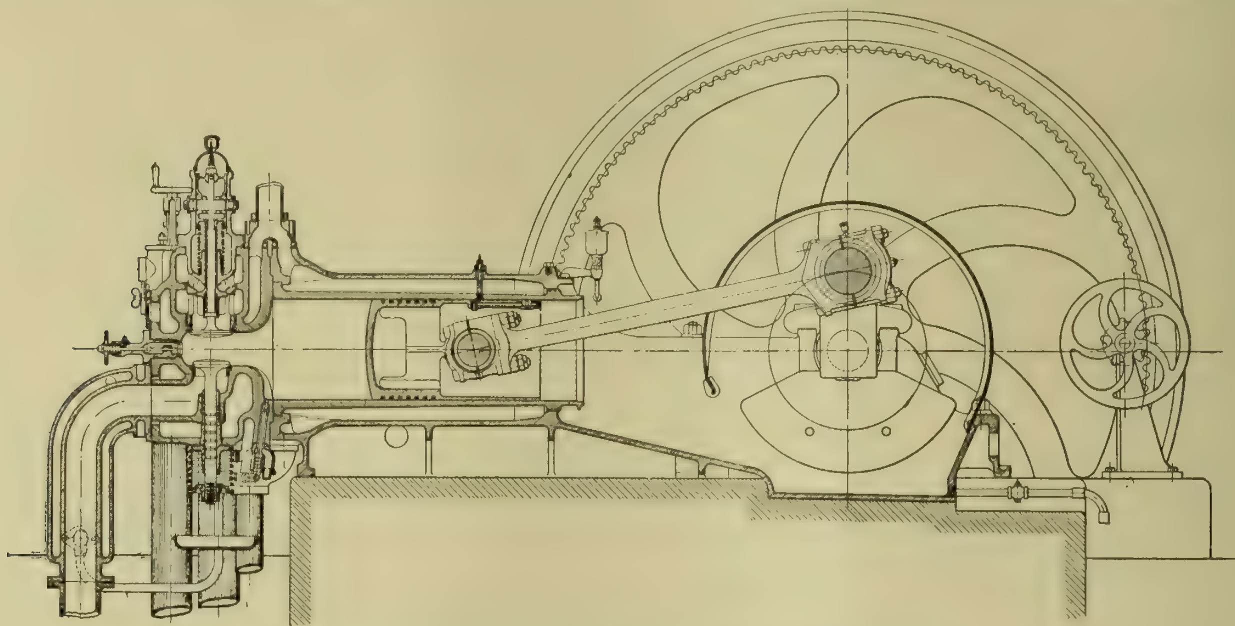


FIG. 1.—CROSSLEY GAS ENGINE. LONGITUDINAL SECTION.

cheapened the engine, and although improvements in detail and design mark the passing years, the mere cheapening of the engine in order to obtain a reduced first cost is not in the direction of true economy or efficiency.

In the modern gas engine we should not aim at cheapness, but rather at producing an engine that combines a graceful exterior with a powerful structure, an economical consumption of fuel at all loads, with steady reliable running and wearing qualities, and a long life; all materials should be of the very best obtainable quality and suitability for the particular work they have to perform, and prepared for their work by the most up-to-date processes so as to ensure absolute accuracy as well as interchangeability. Where heavy frictional loads occur, special material with hardened surfaces must be supplied and the whole mechanism supplemented with a perfect system of lubrication.

Figs. 1 and 2 show sectional views of a Crossley gas engine, an examination of which shows at once the beauty and strength of the proportions of the modern engine. In passing, it will interest you to know that our chief engineer, Mr. Wilfred Webb, who is responsible for this design, was once a student at your college under Professor Robinson.

Of the whole engine, the breech end requires the greatest skill both in design and manufacture, and the design shown is held in high reputation by leading insurance companies for its absence from fractures and reliability under the most exacting conditions. The combustion chamber within the breech end is of symmetrical shape, and having the least possible amount of cooling surface, ensures a maximum of the heat of the fuel being converted into work. The design allows for free expansion of all parts with as few joints as possible. All the valves, namely, gas, air and exhaust, are vertical.

Quoting from a recent publication, "The Construction and Working of Internal-combustion Engines," by a well-known continental engineer, he says that "the influence of the shape of the explosion chamber upon the efficiency of an engine is manifest. The enclosure within which the combustion at high temperature occurs from a thermal standpoint should prevent a minimum of cooling surface. Explosion chambers should be short and regularly shaped and arranged as an extension of the cylinder. Moreover, for ease of construction and rational disposition of valve mechanism, the valves, as far as possible, should be arranged vertically and in the same axis."

The breech end of the gas engine illustrated conforms to these important characteristics. Long experience justifies the wisdom of its design. The publication referred to, then goes on to show and criticise a faultily-designed explosion chamber with the charge admission valve arranged behind the exhaust valve, necessitating an excessively long chamber, which prejudices not only the rapid propagation of the flame, but also greatly increases the cooling surface of the chamber. Such an arrangement also complicates the design when dealing with the valves, examination covers and the passages for gas, air, exhaust and ignition, and, last but not least, the enveloping water jacket. There is also always the danger of pre-ignition troubles due to the overheating of the unwatered valve covers.

When the best has been made of such a design there is practically no alternative open in order to make a satisfactory piece of mechanism, but to split it up into a number of parts, involving extra cost in machining, jointing and bolting, in order to construct the complete breech end. It does not need much demonstration to show the serious disadvantages already stated, and the risks which are involved in the number of joints and the losses incurred in the irregular shape of the combustion chamber and the excessive cooling surface exposed to the flame. In some designs of this type of breech end as many as eight joints are required to make up the breech-end, some of them double joints, leaded on one side by the explosion pressure and on the other by water pressure. These double joints particularly require very careful handling to ensure that when one is tight the other is equally

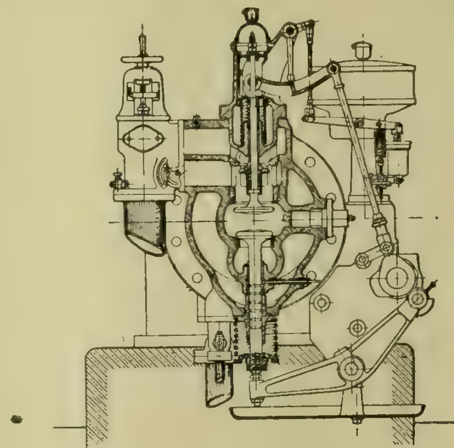


FIG. 2.—CROSSLEY GAS ENGINE. CROSS SECTION.

tight. In my opinion, these joints must be always a great source of trouble and unreliability. It may interest you to know that this type of breech end was discarded many years ago by continental makers, and is now quite obsolete.

In contra distinction to this "faulty designed" breech end, we return once more to the engine we are now considering. You will notice from the section that only one joint

is exposed to the explosion pressure, and that by interlocking of the circumferential flange of the liner with the water jacket, water pressure is prevented from attacking the packing in the joint. Other practical advantages in this design are as follows:—

(1) There are no fixing studs or bolts in the water-jacket space, where they would be liable to corrosion; many consulting engineers will not accept bolts or studs passing through the water space for this reason, but always prefer the bolts to be outside where they are in sight and get-at-able for examination and adjustment, which can be easily done, if necessary, when the engine is at work.

(2) There are no unwatered valve covers, the admission valve block forming the cover for the exhaust valve.

(3) The exhaust valve head is thoroughly cooled by the incoming charge admitted from the super-imposed admission valve. Under such conditions it is not necessary to water-cool the exhaust valve.

(4) A blow-off valve is arranged to drain any accumulations within the compression space.

(5) An economical and simple form of combustion chamber is obtained in one casting.

(6) As the quality of the combustible charge is always constant, it is not necessary to fit double electric ignition, which is a necessity in the case of the "faultily-designed" breech end just referred to.

(7) The extended bedplate, supported for its whole length upon the concrete foundation, is not only rigid and substantial, but eliminates vibration and noise; also, there is an oil channel provided all round the sides and front of the bedplate in order to prevent waste of oil and deterioration of the foundation.

(8) The old form of conical plug cock for the regulation of producer gas is replaced by a screw-down valve. This is not liable to stick fast, however dirty the gas may be, due to imperfect cleaning, for this valve has greatly reduced contact surfaces. Also smaller gas cocks for town's gas are arranged so that the conical plug can be removed for examination and cleaning without disturbing the gas pipes.

(9) The valve gear for operating the air, gas, admission, governing, and exhaust mechanism is controlled by two cams only. These cams, together with the rollers and pins, are manufactured of special steel, hardened and ground to limit gauges.

(10) The materials of construction are subject to very severe physical and chemical tests, and, after manufacture, all parts are carefully inspected as to correctness to limit gauges and to hardness and general suitability, thus ensuring the highest possible perfection in the finished engine.

We now come to the consideration of gas engine governing, which is of the highest importance in an impulse-governed engine deriving its power from a succession of explosions. It is not long since the well-known hit-and-miss governing system was a standard type, and some may ask why so simple a method of governing has been discarded. It is well known that the system of throttle governing in a variety of forms has been almost universally adopted by all the best makers. What is it, then, that makes the throttle superior to the hit-and-miss gear? The superiority of throttle governing is proved from the fact that it meets the modern conditions requiring greater steadiness and regularity, and also that the engine runs more quietly, smoothly, and regularly at all loads, and, in contra-distinction to the hit-and-miss, as the load is reduced the regularity of running increases, so that at about half-load the regularity is about twice as good as in an engine fitted with hit-and-miss governing. The life of the engine is also greatly prolonged, owing to the reduced temperatures and pressures at which it works on average loads. These advantages naturally react upon all the driving machinery, comprising ropes, belts, friction coupling or clutches, &c., all of which, because of the smoother and more regular running of the prime mover, are subject to less straining and therefore require less attention, upkeep and replacement.

On the contrary, the regularity of engines governed on the "hit-and-miss" system decreases as the load decreases, with the result that at about quarter-load the irregularity of running is about four times worse than with a throttle governing engine under similar conditions of load. Again, in the "hit-and-miss" engine the quality and quantity of the power charges following the idle strokes are upset owing to the change of conditions within the cylinder. These conditions may result in either a too weak or too heavy explosion; usually it is too heavy and the shock of it acts detrimentally upon all the working parts and introduces mischievous cyclical irregularities, which are clearly seen in the fluctuations of the driving ropes or belts when the engine is running at or below half-load. In order to overcome these disturbances the usual practice was to increase the weight of the flywheels, which would still further limit the serviceableness of the engine by adding to the loads and strains imposed upon its shaft and bearings.

Further, it is now generally admitted that a well-designed throttle governor gear can obtain as good a gas consumption as the "hit-and-miss" gear. Recently Messrs. Crossley Bros. tested the two systems upon an engine which was first fitted with the "hit-and-miss" and then afterwards with the "throttle" gear, all other conditions remaining constant, and the mean results clearly proved that from full to half-load the lowest fuel consumption was obtained with the throttle gear. Below quarter-load the "hit-and-miss" had a slightly better economy, but with all the other disadvantages already enumerated. The average consumption, however, was better with the throttle governed engine, because the better economy was obtained at the higher loads when more gas per hour was being used. The chief consideration must always be in the

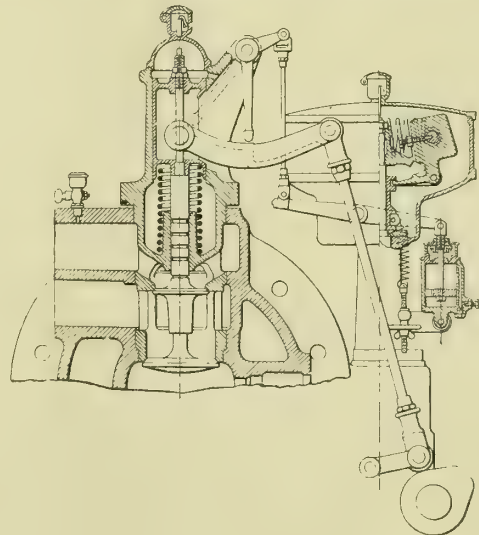


FIG. 3.—PATENT ADMISSION VALVE, GOVERNOR, AND GOVERNING GEAR.

direction of the reduction of running costs, and in this the throttle governed engine proved to be easily first.

The throttle governing gear best suited for general requirements and which should be fitted to the modern gas engine can be of the simplest description, comprising few working parts; or it may be elaborated and complicated so that its mechanism is neither easily understood, nor maintained at its best efficiency. There are a great variety of throttle governing gears, patented and unpatented, upon the market. The earliest form for gas engines was introduced by Mr. John Fielding, of Gloucester, which consisted, I believe, of separate butterfly throttle valves placed in the gas and air pipes. One of the outstanding features of the Crossley engine is the patent throttle governing gear, which is both simple and efficient.

As already mentioned, there are other governor gears which attempt to gain a similar efficiency, but have many more parts, requiring additional adjustment, which are liable to greater wear and tear, and eventually cause imperfect governing, irregular working, and uneconomical results. The mechanism of the Crossley gear, shown in Fig. 3, has only two essential parts, namely, a movable fulcrum and a radius lever. This gear has now a world-wide reputation, and in referring to it, Mr. Mathot, a well-known gas engine authority, says: "From the long period which elapsed from the time of the application to the time of granting the patent, it is obvious that the Patent Office has thoroughly investigated the matter and carefully examined the different anticipations which might have been alleged. If after this

examination the patent has been granted, this constitutes a recognition of the rights of the owners to benefit by this invention, and to prevent any other constructor from making use of gear employing similar principles."

Again quoting Mathot, he says: "This gear is considered amongst the best. It is simple, rational, and neat, and it has been proved in practical use that its working is excellent."

Let us examine carefully the characteristics of this gear, which has now been fitted on some thousands of engines. In the first place, the most important feature is its extraordinary simplicity. The variation in the lift of the inlet valve is effected by simply moving the fulcrum of the inlet valve lever. Another item of importance is that the gear being always in full view, the attendant knows exactly the power and regularity at which the engine is working by simply noting the position of the movable fulcrum. This system of "quantity" regulation, in which the main inlet valve itself becomes the throttle valve, is unquestionably the best of all systems for controlling the gas engine, because the impulses are not only given on each working stroke, but they are reliable at any position of the governor, which is not the case when engines are working with what is known as "quality" regulation. Also, the consumption of fuel is better with this system of regulation when the engine is working on reduced loads, owing to the greater expansion of the initial charge. For instance, when running at no load the ignited charge expands to more than twice its volume with "throttle" or "quantity" governing, but only to its original volume with "quality" or "hit-and-miss" governing.

Another highly important characteristic of "throttle" governing is that when the engine is working on lighter loads, the compression and explosion pressures are reduced, thereby reducing the strains and friction on all working parts in proportion to the power, and thus giving the engine a much longer life. In order to illustrate this clearly, the five indicator diagrams (Fig. 4 to 8), taken from an engine working at different loads, show the reduction in the compression pressure and in the explosion and mean pressures, while at the same time retaining a high fuel efficiency. This system of governing by varying the strength of the impulses will be especially appreciated in the case of electrical, weaving, spinning, and other work, and especially for alternating-current electrical machines requiring an extremely even turning moment, because the steadiness of running increases as the load decreases. The centrifugal governor controlling the variable admission gear is of a heavy, powerful type, with all its working parts enclosed in a stationary oil-tight casing and its gear wheels immersed in an oil bath.

The main feature in this system of governing is the fact that the admission valve is itself the throttle valve, and directly controls the admission of the air and gas mixture, and also the amount of suction that acts within the passages behind the valve. By this means the suction on the gas valve behind the admission valve is decreased as the power charge is reduced to suit the load, and the consumption of gas is thereby reduced automatically as the load is reduced. Therefore, it follows that whether town gas or producer gas is used, when once the mixture has been adjusted, it remains practically constant, so that a maximum of efficiency is obtained at all loads.

Now there are several designs in which the throttling is effected by two auxiliary valves of the mitre or wing type behind the admission valve. In this case the admission valve opens wide at all loads, and therefore the suction on the gas valve behind it increases as the load is reduced. Under these conditions, if the engine is arranged to work on producer gas, and the quality of the gas changes, there is a considerable waste of gas, particularly at the light loads, greatly increasing the running costs. This is because the full suction acts directly on the gas throttle valve. How much more difficult, then, must it be when the engine for some reason has to be changed to a much richer gas, such as town gas, where the consumption of town gas per hour at no load may increase to such an enormous extent as to be even greater than at full load. Herein lies the reason why some makers do not recommend throttle governing with engines to run on town gas, as the consumption of gas becomes prohibitive at reduced loads. With the gear used on the Crossley engine, when the engine has been running on suction gas and requires to be changed over to town gas or gas of a different calorific value, all that needs to be done is to close the producer gas cock and open the town gas cock, the engine continuing to run perfectly on full or varying loads with either fuel, as may be required, and at a high fuel efficiency for all loads, the average efficiency being even better than on engines governed on the hit-and-miss system and far better than with "quality" governing. Therefore, with the Crossley gear, control is maintained over both the speed and the gas consumption, but in the other gear it is maintained over the speed only, as the governor can absolutely lose all control over the fuel consumption.

Even with an engine of well-designed proportions there always remains the possibility of trouble if the lubrication of the working parts is not effectually and continuously main-

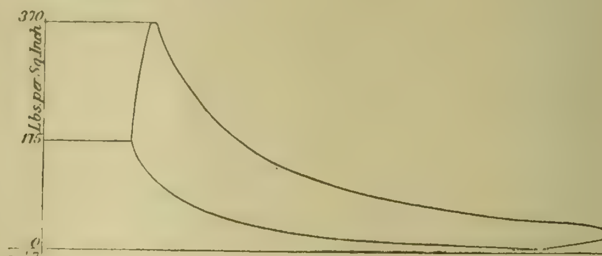


FIG. 4.—FULL LOAD.

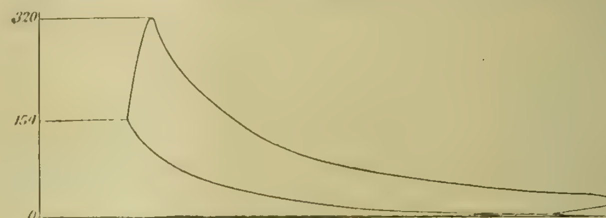


FIG. 5. THREE-QUARTER LOAD.

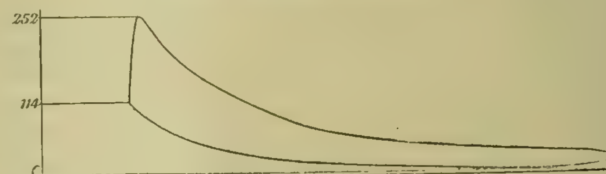


FIG. 6. HALF LOAD.



FIG. 7. —QUARTER LOAD.

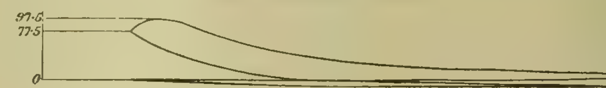


FIG. 8.—NO LOAD.

tained. Lubrication of the internal-combustion engine is a matter of the very highest importance. It is not sufficient to have the lubricant in the lubricators, but the arrangements must be so designed that the lubricant reaches the surface requiring it with absolute certainty. The oil must therefore be of the correct quality, must be pure, and the passages themselves must be made wind and dust proof, so that, as far as it is practicable, nothing can be drawn into the system that may tend to clog the oil pipes and increase the friction between the wearing surfaces of the bearings. In the modern gas engine the cylinder, and in larger engines the piston pin, crank pin, and exhaust valve, are all lubricated by means of force pumps placed in a dust-proof central lubricator. This is usually mounted in a convenient position on the engine frame, and the pumps are worked by an eccentric on the engine side shaft. Also the amount of oil delivered to each of these parts is adjustable, and each drop passes through a sight-glass, so that the attendant can at all times see that each part is properly lubricated. After the cylinder and crank shaft bearings, the large and small ends

of the connecting rods are perhaps those needing extra care in treatment. There are many designs of lubricating arrangements to the crank pin which allow dust or dirt being readily drawn in along with the lubricating oil because the design of wiper or ring oiler is not dust proof. In the Crossley engine a dust-proof ring is provided for collecting the oil, which then is continuously carried to the wearing surfaces by centrifugal force. Dust-proof arrangements are also provided for the crank-shaft bearings and side shaft bearings—all are lubricated by enclosed oil rings revolving on the shafts, the lower half of the rings being immersed in oil baths supplied with sight gauges As an additional safeguard two oil rings are provided for each bearing, both on the crank shaft and side shaft, to ensure a continuance of lubrication in the event of one ring ceasing to revolve, which is a very rare occurrence indeed. All these provisions, as can be well understood, allow for continuous night and day running. The gear wheels also run in oil baths, and where necessary, oil-retaining grooves, rings, or trays are provided to prevent oil being thrown about. This conduces to economy and ensures the engine-house being kept clean. The consumption of oil for lubricating purposes averages 0·003 pint per brake horse-power per hour, but there are many instances of engines, in the hands of careful and experienced men, running satisfactorily down to nearly half this amount. For instance, in the works of the United Alkali Company, there is an engine of over 100 h.p. which has for over six years been running 165 hours per week continuously on an oil consumption of 4 galls. per week. This works out to 0·00149 pint per brake horse-power per hour at full load.

The final consideration is the variety of fuels that can be utilised in the gas engine. At the present time there are many gas-engine installations at work utilising fuels that would be quite unsuitable for the raising of steam power. Generally speaking, anthracite coke or ordinary coal slack are the fuels used in gas plants, but special plants are constructed which deal successfully with wood and bark refuse, varying in size from comparatively large pieces down to shavings, and from matchwood refuse to fine sawdust. Plants are also running satisfactorily on charcoal, cotton seed, and tan refuse. In the case of tan-refuse plants, this method of disposal is very convenient and economical, and obviates any necessity to purchase fuel from outside, thus making the user independent of the rise in the price of coal. Plants can also successfully use olive refuse, coffee husks, cocoa husks, cocoanut fibre and shells, smokebox char, coke breeze, sugar-cane refuse, sewage sludge cake with coal dust pressed into it, cotton pod husks, and even recently a firm sought to utilise red currant and blackberry jam refuse. There is no objection to this, providing the quantity is sufficient to justify a gas plant, and the necessary conditions as to percentage of moisture are covered.

Recently, extremely successful results have been secured when using suddite, or sudd of the Nile, as fuel. This is composed of the stalks of certain tropical plants which grow and abound in the waters of the Nile to a height of several feet, and form a serious obstacle to navigation. By a new process they are now cut down and turned into pulp. This is afterwards pressed into briquettes, and has been used with complete success, as also the dry stalks themselves without any briquetting, so that the formerly useless waste product of the Nile has been rendered available as a valuable fuel in a region where ordinary fuels are extremely scarce.

An independent test of an installation using wood waste was recently undertaken by Mr. R. E. Mathot, of Brussels, at Molenbeck, in Belgium. His test took place in July of this year. His report is as follows: The engine is a horizontal two-cylinder type, developing a maximum b.h.p. on producer gas of about 80, and is fitted with valve gear on the "variable admission" principle, which changes the The ignition is effected by low-tension magneto and "make and break" spark box, the spark being within the cylinder. and brake" spark box, the spark being within the cylinder. The main dimensions are: Diameter of piston, 12in.; stroke, 21in.; speed, 210 revs. per minute. The Crossley gas plant used is composed of a generator gasifying wood chippings, shavings and sawdust, a tar separator, and a coke scrubber The tar extractor is of the Crossley centrifugal type, whereby gas is induced from the centre of the inlet to the impeller, passing to the periphery and returning to the centre of the impeller. The particles of tar in the gas are separated out by centrifugal force and thrown against the casing. The gas is submitted to a double-beating action, and the kinetic energy imparted to the incoming gas is given out on the return flow of gas to blades on the outlet side of the impeller. A stream of water is fed to the centre of each side of the impeller.

The object of the tests was to verify power consumption, and the general working conditions of the installations. Prof. Mathot states that during the first day he verified the general working conditions, the working of the various apparatus and the accuracy of the instruments. The second day was exclusively taken up by the test proper. The engine was loaded by means of the "Mathot Prony brake," the latter being water cooled. The arm of the brake having a length of 1·66 metres tested directly on the scale, which had been previously balanced. Indicators, the springs of which were tested both before and after the tests, were fitted to each cylinder, and a speed counter to one of the sideshafts registering the speeds of the engine. During the tests and concurrently with the mechanical analysis of the gas, about 20 calorimetric tests were made by means of a Junker's calorimeter. The gas required for these tests was taken from the plant immediately behind the tar separator. For determining the indicated power and to check the general behaviour of the engine, diagrams were taken every quarter of an hour. The quantity of water required for cooling the engine was checked by measuring during a given time the quantity of water leaving the cylinders. The measurement of consumption was effected by weighing all the wood waste put into the gas plant during the whole period of the tests. The fuel was composed of mixed beech and oak chippings just as they were collected from the woodworking machines without having been previously dried or freed from dust. The engine was loaded up for the first time at 7-15 a.m. with a load of 385,809lbs. on the scale; this load was sustained for a quarter of an hour at a mean speed of 208 revs. per minute, and corresponds with 81·063 b.h.p. At 7-30 the scale was loaded with 330,738lbs., a load which was sustained during the whole of the test, making a total length of $9\frac{3}{4}$ hours continuous run, during which the work absorbed by the brake was 72·25 b.h.p. The mean number of revolutions was 210·1 per minute. To the power of the engine, full and normal, an overload should be added, 12·861 b.h.p. absorbed by the high speed shafting from which was driven a water circulating pump and the tar separator, as well as the pulley of the air compressor. This power was determined from diagrams taken when the brake was released. Under these conditions the total work at full load was $81·06 + 12·86 = 94·92$ effective h.p. The power at normal load was $72·25 + 12·86 = 85·11$ effective h.p. During the whole of the trials the engine and gas plant worked perfectly regularly, and not the slightest trouble was noticed. It is worthy of note that the installation was sold for 75 b.h.p. normal load, sustained 85·11 b.h.p., having an overload of almost 15 per cent. The consumption, namely, 2·64lbs. of wood refuse per effective horse-power, is remarkably low.

The installation does not require any special care, and from the point of view of low consumption and facilities for driving, is a form of power to be highly recommended in sawmills and large works producing chippings, shavings, and other wood refuse. The latter fuel can be used without the addition of any other kind of combustible, the expense of which will be practically nil. In addition, the tar produced is of excellent quality, and averages about one bucketful per day with an installation such as we have tested. This tar forms a marketable by-product.

There are almost numberless intensely interesting features and possibilities associated with the modern gas engine which cannot adequately be dealt with at this time—perhaps at some future date items similar to the following might most profitably form the subject matter for consideration, viz.:—

Increase in power units of horizontal, vertical, and inverted vertical multi-cylinder types.

Gas engine suitability for continuous running and steadiness for alternator driving in parallel.

The easy and reliable starting of gas engines by means

of compressed air, and, when necessary, against a full load factor.

The comparison of thermal and mechanical efficiencies of various types of internal-combustion engines with steam reciprocating and turbine engines, and, finally, the possibilities of gas turbine construction.

But with all the unavoidable limitations associated with this lecture, I shall feel well repaid if you agree with me that the British-made gas engine on the lines enunciated is still pre-eminent in the markets of the world.

THE NORTON CYLINDRICAL GRINDING MACHINE.

We illustrate herewith a cylindrical grinding machine of the type in which the grinding wheel is moved bodily toward and from the work, either by hand or by power. In this machine, which has recently been patented by the Norton Grinding Company, Worcester, Massachusetts, U.S.A., the wheel can be operated by hand and by power at will, while the hand-operated mechanism can be disconnected very readily from the wheel-operating mechanism when it is to be operated by power. Means are also provided whereby when the wheel has been brought up by power to the limiting position it cannot be moved farther in that direction by power until the machine is reset, so that danger of bringing it too far up after truing the wheel or replacing it is avoided.

Fig. 1 is an elevation of a wheel case showing the wheel in contact with the work. Fig. 2 is a transverse sectional view through the wheel-operating shaft and connected parts; and Fig. 3 is an elevation of the same partly in section. Ordinarily the wheel and wheel casing are moved very slowly toward and from the work by an arrangement comprising a rotary handle 1, a long-faced pinion B, and a gear C on a shaft D, which carries a worm E for moving the casing A back and forth. The power-operating means for moving the casing A comprises a handle 2 on an oscillatable shaft F which is provided with a lever connected with a reciprocable rod G carrying springs and an operating member for operating a double-faced clutch H. This clutch is designed to connect the feed drive shaft J with a shaft K through a set of bevel gears for the purpose of rotating the shaft K in either direction from the feed drive shaft. This shaft K is connected by gearing with the shaft D. It will be seen, therefore, that the shaft D can be rotated in either direction by power or by hand, independently of each other.

The shaft D is connected with the wheel C by a hub L keyed to the shaft and having rotatably mounted thereon a bushing for the hub of the gear and provided with a pair of circumferential grooves M. Radial pins N in the hub of the gear C are pressed inwardly by a circumferential spring so as to engage in either one of these grooves. The gear is provided with a projecting flange 3 adapted to be grasped by the hand for the purpose of moving the gear back and forth so as to bring it into either of its two positions on the bushing. In the position shown in the drawings, teeth O on the hub of the gear engage between teeth P on the hub L, and consequently the rotation of the pinion B is transmitted positively to the shaft D or vice versâ. But when the flange 3 is pulled back, so that the pins N engage in the other groove M, there is no engagement between these teeth and consequently the shaft D can operate without spinning the rotary handle 1 around.

On the hub L is arranged a bushing on which is carried a pinion Q. This pinion meshes with two gears R and S. One of these gears R is fixed with respect to a bearing on the frame in which the shaft D rotates. The other gear S is rotatable on this bearing and carries with it a larger gear T. The two gears R and S are of the same size, so that they can both mesh with the pinion Q, but they are provided with different numbers of teeth, one of them having one more tooth than the other. The gear T meshes with a gear U which is mounted to rotate freely on a bearing on the frame, this bearing being concentric with the gear B. This gear U is provided with a conical friction surface which is engaged by a similar surface on a wheel V, also free to rotate on the hub of the gear U. This hub is provided with screw threads on which is a pilot wheel 4 adapted to screw up on the threads and force the wheel V inwardly, so as to cause the two friction surfaces to engage each other firmly and cause the gear U and wheel V to rotate together. On the wheel V is a block W which, when in one position, engages a sliding rod X mounted in a bearing on the frame and moves it into a position in which it will engage a projection Y on the shaft F and prevent the movement of this shaft beyond the centre of its oscillation. That is, it will prevent the handle 2 being turned to a position to connect the clutch H with the shaft J to rotate the shaft D in one direction, that is, the direction to move the wheel toward the work. On both the wheel V and a concentric surface of the frame are permanent marks. Now when the grinding wheel has been brought up to position toward the work, and has to be withdrawn for truing up or any other purpose, it is obvious that it will be necessary to bring the wheel back exactly to the same point. Consequently, the operator loosens the pilot wheel 4 and turns the wheel V until the marks just referred to register. Then the block W comes into the position shown in Fig. 3. The pilot wheel is then tightened up. This having been done, it will be obvious first, that the grinding wheel cannot be moved any further toward the work by power, and second, that when it has been moved away from the work and then brought up again, the block W will always come back to this position when the wheel comes back to its original extreme position. In this way it will be seen that after the machine is once set there is no danger of the operator bringing the grinding wheel up too far by power or of stopping short of the proper position to commence to finish the work. As has been stated, when reciprocating the grinding wheel by power, the spinning around of the rotary can be prevented simply by pulling out the hub 3.

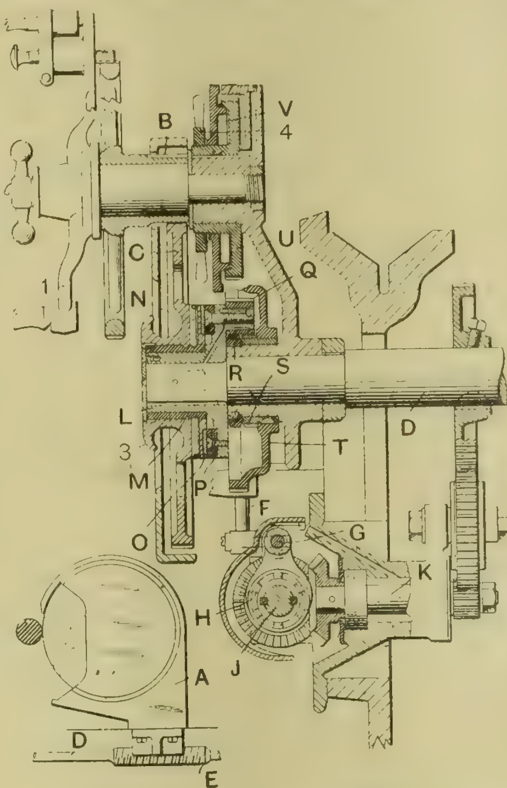


Fig. 1.

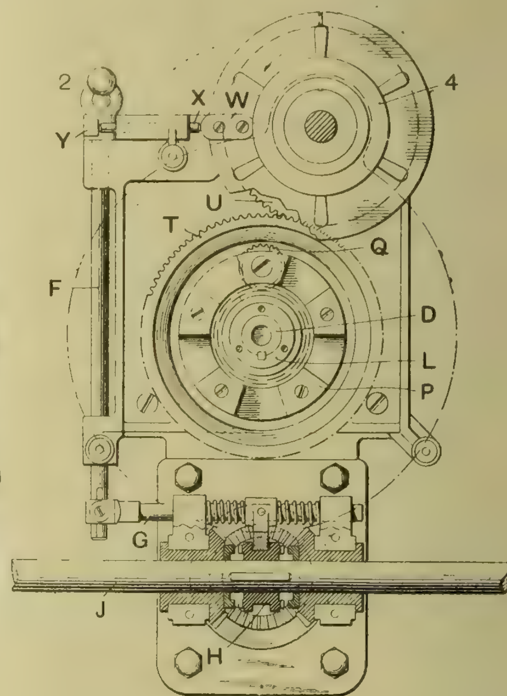


Fig. 2. Fig. 3.

Norton Cylindrical Grinding Machine.

DEVELOPMENTS IN OPEN-HEARTH STEEL PRACTICE.*

BY N. E. MACCALLUM.

ALMOST half a century has passed since the Siemens brothers, after tedious and costly experiments, finally began the manufacture of open-hearth steel. The furnace of that time was very small, having a hearth capacity of from 3 to 4 tons, and we can appreciate the wonderful development that has taken place in those 50 years by the knowledge that to-day furnaces of 50 times the original capacity are in operation. As the new steel process assumed importance, and furnaces began to grow in number and in size, a question arose, to which no satisfactory answer has ever been given, and that was: "What is the safe and economical limit of the open-hearth furnace?" Various stopping places have been suggested, and 20, 30, 40, and 50 tons have each been advocated, but all such arbitrary restrictions have been passed, and 60 tons would probably represent the average furnace, although in a few instances from 70 to 80 tons are regularly tapped into one ladle. The furnaces which are the subject of the present paper have gone far beyond even these limits, and since, in my opinion, they mark another step in the progress of open-hearth steel, they will be considered fairly and frankly, in order that those to whom the matter may be of interest may be able to judge and form their own conclusions.

These furnaces are operated by the Phœnix Iron Company, Phœnixville, Pa., and their distinctive and important feature is that they charge to twice the capacity of one ladle, and tap simultaneously into two ladles, with a device for controlling the flow into either. In this way the capacity of the furnace is not limited, as formerly, but heats of any size within the capacity of two ladles may be charged. The ultimate reason for charging furnaces beyond the normal amount is not that large heats may be made, but because by making large heats a material increase of product is obtained.

A plan of the divided spout, pits, and ladles is shown in Fig. 1. In order to make the branches of the spout as short as possible, one ladle is placed slightly in advance of the other, which also enables the trunnions to clear. Fig. 2 is a plan and a front elevation and Fig. 3 a side elevation of the device for controlling the flow of steel into either ladle. Its purpose is not to stop, but merely to check, the flow. The levers by which it is operated are placed from 20ft. to 30ft. from the centre of the furnace, and the controlling rod is protected by firebrick, much the same as the ladle rod.

The first of these furnaces, here designated A, B, and C, was completed early in 1909. The area of the hearth was 32ft. by 14ft., and was a fair average of furnaces charging from 50 to 55 tons of materials. At that time no thought had been entertained of breaking away from the established practice, but, on comparing the capacity of this hearth with those of our smaller furnaces, it proved to be so much in excess that the question was raised as to the advantage of a large hearth if it could not be fully utilised. Various experiments were then undertaken to determine the feasibility of using two ladles, and the best means of controlling the flow into either ladle, which resulted in our present practice.

Furnace B, completed in September, 1909, was the same in all respects as furnace A, except that the hearth was lengthened 4 feet, making it 36ft. by 14ft. in area. Furnace C was built in 1911, the size of the hearth being increased to 42ft. by 15ft. The size of the regenerator chambers was also increased. These chambers were designed to meet existing conditions. The air chambers of furnaces A and B are 9ft. wide, and the gas chambers 6ft. wide. For furnace C the air chambers are 12ft. wide and the gas chambers 8ft. wide. The length of chambers and depth of checker work are uniform for all the furnaces, 18ft. and 7ft. respectively. If these furnaces are rated as 115 tons, 130 tons, and 165 tons capacity, which is the usual weight of ingots tapped from each, it will be noted that the checker space on each end of the furnace is only equal to about 15 cub. ft. per ton of hearth capacity; or, one-sixth of the amount generally allowed and recommended by prominent metallurgists. This statement is not made from any desire to criticise or detract from the prevailing views and practice; but it might be worth while to note that, had this practice been followed, the depth of checker space in furnaces A, B, and C would have been 46ft. instead of 7ft. Or, to state the same thing in another way, the rated capacity of the furnaces, based on checker space, would be 19 tons for furnaces A and B and 25 tons for furnace C, instead of 115, 130, and 165 tons. It may therefore be safely assumed that any particular merit which this practice possesses must be attributed to causes other than the chambers.

The areas of the hearths of furnaces A and B were practically the same as those of ordinary furnaces rated at from 50 to 55 tons capacity, and that of furnace C, 42ft. by 15ft., giving an area of 630 sq. ft., is almost an exact duplicate of the area of a number of furnaces recently completed and rated at 60 tons. The hearths are of the usual depth, and measure from pan-plate to top of foreplate 5ft. 0·5in. The pan is covered with 18in. of brick and from 10in. to 12in. of magnesite in front of the tap hole. If, therefore, the hearths are of the same size, and the chambers are much smaller

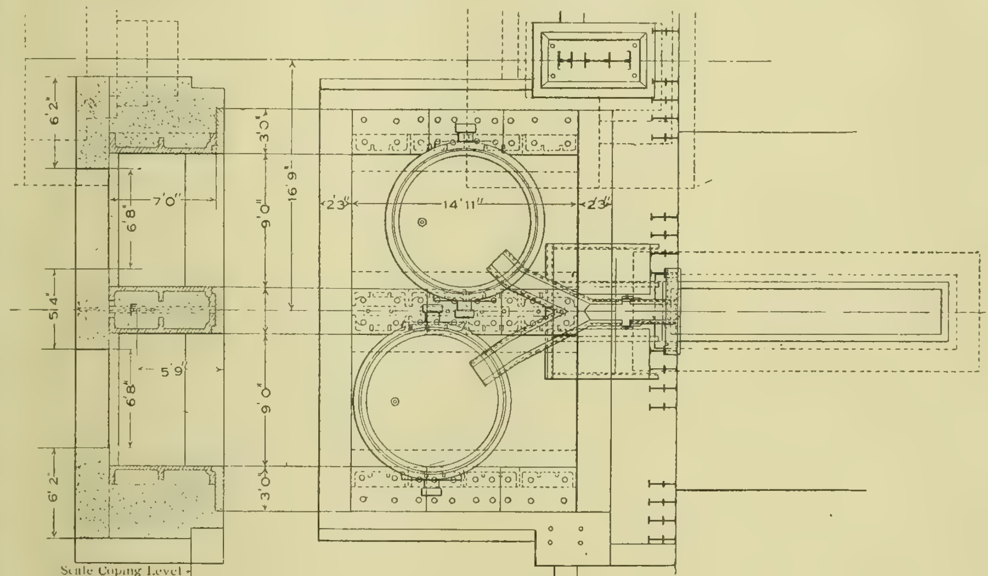


FIG. 1.—GENERAL PLAN OF THE TWIN LADLE PIT AND SPOUT FOR OPEN-HEARTH FURNACES OF LARGE CAPACITY.

than those of many other furnaces, it is apparent that the large tonnage must be due to other reasons, which we shall endeavour to show lie not in the furnace, but in the practice.

On one occasion, in discussing methods of operation with the superintendent of a large steel concern, I asked if he reduced the size of open-hearth heats at the week-end, and the reply was that he did not, as it had been found that a large heat could be made almost as quickly as a small one. That was the open-hearth man's way of broadly stating a truth, which was not intended to be accepted too literally. It is not true, of course, that a large heat can be made as quickly as a small heat, but it is true that steel is made faster in a large unit than in a small one. This seems an obvious fact, yet it is one that receives but little attention, and is rarely considered in comparing the work of one furnace with another. In most works, the number of heats which each furnace makes weekly constitutes the basis of comparison: but it is evident that for furnaces of different capacities it would be of little value, since the small furnace might make more heats and yet not equal the tonnage of a larger furnace, or, in furnaces of similar capacities, one might be delayed with repairs to hearth or otherwise and show a decreased tonnage, although it might be a faster working furnace.

For a number of years I have used, as a basis of com-

* Paper read before the American Institute of Mining Engineers.

parison, the time from beginning the charging until the tap hole is open, divided by the product, which gives, in minutes per ton, the rate at which steel is being made. This gives a reliable means of determining the speed with which any furnace is capable of making steel, and also its ability to compete with other furnaces. Using this method of comparison, Table I. has been compiled from furnace records of the Phœnix Iron Company. In every case the record covers a period of not less than six months, and should be fairly representative of the work done by each furnace. The smaller furnaces are of the older type with regenerators underneath the hearth, but did efficient work and compared well with other furnaces of similar construction. Furnace C was built on the site formerly occupied by two of the smaller furnaces, Nos. 5 and 6, and it is interesting to note that furnace C is making steel just a little more than three times as fast as No. 5 formerly did.

TABLE I.—*Data of Furnace Practice.*

Furnace.	Hearth area.	Weight of ingots, tons.	Time per ton. minutes.
No. 3	17·5 × 12ft.	30	32·79
No. 5	20ft. 3·5in. × 12·5ft.	40	26·48
No. 1	24ft. × 12·5ft.	50	19·66
A	32 × 14ft.	115	11·50
B	36 × 14ft.	130	10·50
C	42 × 15ft.	165	8·68

A study of Table I. will reveal two significant facts: One, that the economical limit, so far, at least, as time is concerned, has not been passed, since furnace C is shown to be making 21 per cent. faster than furnace B. The other, the striking decrease in minutes per ton as the hearth area and unit of steel increase, and it is on this fact that the practice of the Phœnix Iron Company is based. The extent to which any furnace may add to its product will be proportional to the excess charged over the normal one-ladle heat, but from the experience of the Phœnix Iron Company, it may be affirmed that by doubling the normal charge the product of any furnace can be increased by from one-fourth to one-third; that is, if a furnace charging single-ladle heats can produce, say, 600 tons weekly, it will, by charging double-ladle heats, produce from 750 to 800 tons. This can be demonstrated rapidly by operating any furnace alternately on single-ladle heats and half-ladle heats, and comparing the number of minutes required in each case to make a ton of steel.

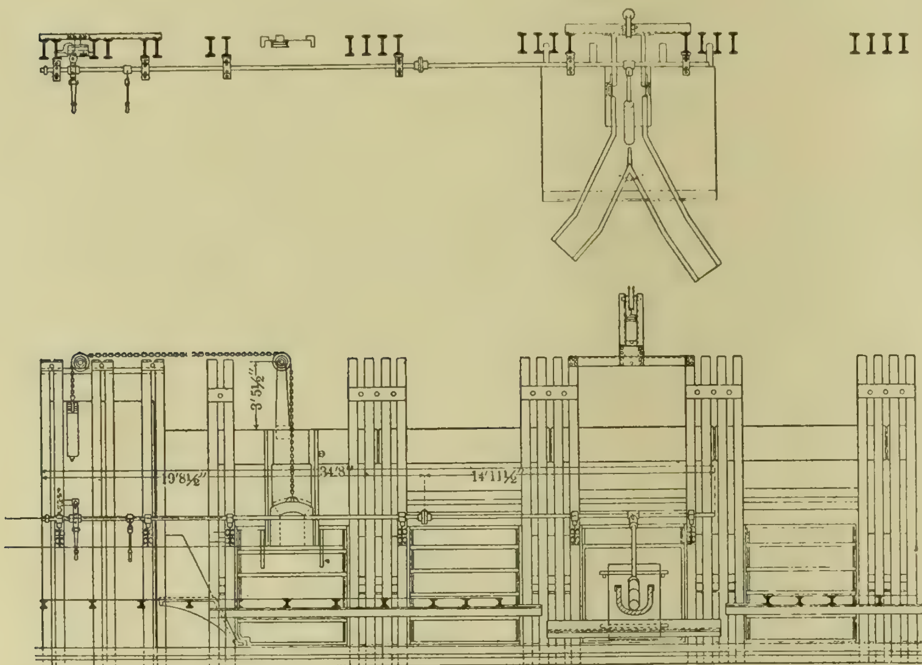


FIG. 2.—PLAN OF STREAM CONTROLLER FOR TWIN RUNNER SPOUT AND FRONT ELEVATION OF OPEN-HEARTH FURNACE.

Why should steel be made faster in large units than in small? No particular reason can be assigned, but there are several probable causes which contribute to that result. The first and most important is the economy in time; that is, in a given time more steel will be produced, or the same amount of steel will be produced in less time. This can be better understood by dividing into two periods the time required to make a heat of steel, the first period being the time required to charge the melt and the second period from the time when the lime floats to the surface of the bath until the heat is ready to be tapped, known as the working of the heat. In the first period the double-ladle heat will not show much gain over the single-ladle heat, as it will take almost twice as long to charge and melt, but in the second period, when spar, ore, and other additions are made, the double-ladle heat gains a decided advantage, since it takes but little longer to work a large heat than a small one. At various times during the past three years single-ladle heats have occasionally been made on furnaces A, B, and C, and a careful scrutiny of the records shows that the average time required to make a ton of steel on those heats was 12·2 minutes, while the average time at which furnaces were running on double-ladle heats was 9·7 minutes, showing that it required 25·7 per cent. more time to make a ton of steel on a single-ladle heat than on a double-ladle heat.

As a second cause, it is evident that twice as many single-ladle heats will be required to produce the same tonnage as that from double-ladle heats, therefore one-half the time which would be required to make repairs to the hearth in the former case will be available for making steel in the latter. Then again, each heat of steel that is made, whether large or small, entails two extremes of temperature, the cooling of the hearth and furnace when cold stock is introduced, and the maximum temperature necessary to tap, at which time the hearth and furnace must be raised to at least the same temperature as the steel. It will therefore take twice as many heat-units to raise the furnace and hearth to this temperature to make two single-ladle heats as would be required to make one double-ladle heat, just as in heating water or other substance in a refractory vessel, less time will be required to heat a certain amount in one portion than to divide that amount into two portions and heat each separately, the difference in time being that required to heat the container a second time.

A third cause is radiation. Campbell, in reference to heat-distribution in an open-hearth furnace, says: "Roughly speaking, about one-half of all the heat supplied to an open-hearth furnace is lost by radiation and conduction." That statement concerns the present paper only to the extent that the more frequently a furnace is raised to a tapping temperature the greater will be the loss by radiation, as the latter increases with each degree of increase in temperature, so that the smaller number of heats that are made in proportion to the tonnage, the less frequently will the furnace be raised to a tapping temperature, and the less will be the loss by radiation.

These views have been advanced with some hesitancy, but they appear to offer a reasonable explanation why steel is made faster in large units than in small ones. To confirm these arguments further, a statement of the actual tonnage which each furnace has made is given in Table II. All the stock is charged cold, and the fuel used is producer gas. Furnace C has still five weeks in which to complete the year and should run well over 50,000 tons, which is probably the largest tonnage that has ever been produced from any furnace using all cold raw material.

The saving in cost, which will be proportionately increased as the tonnage increases, depends upon labour, fuel, and repairs. The number of men necessary to operate a furnace on a double-ladle heat is the same as on a single-ladle heat, and if the product is increased one-third, it is apparent that the labour will be reduced one-fourth, including all furnace labour except that of the stock-loaders. The fuel (gas coal), covering a period of several months, will not vary much

whether the furnace is making large or small heats, and, as is the case with the labour, should show a saving of one-fourth. Furnaces A and B are on the same gas line as the blooming-mill soaking pits, and, consequently, it is difficult to get accurate data. Furnace C, however, is supplied from an independent line, and the figures used are based on the actual amount of coal received in the cars.

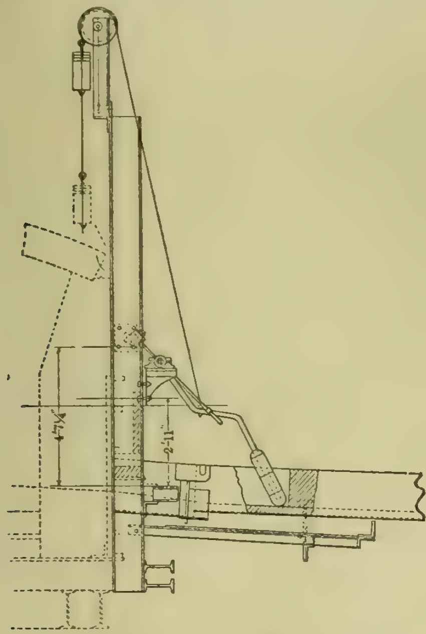


FIG. 3.—SIDE ELEVATION OF STREAM CONTROLLER.

TABLE II.—*Tonnage of Steel Produced.*

Furnace.	Period of time.	Output. Gross tons	Time per ton of output. Minutes.	Fastest time for one ton of output. Minutes.	Largest heat. Gross tons
A	First year	41,436	11·45	8·27	130·04
	Second year	39,910	11·54	—	—
B	First year	43,900	10·38	—	—
	Second year	43,615	10·44	7·49	146·32
C	47 weeks	47,200	8·68	6·92	177·77

On a run of 22 consecutive weeks, including the entire time from commencing the first heat until shut down for repairs, the average amount of coal used per ton of steel was 547lbs. Just whether this represents a saving of one-fourth is uncertain, but we can estimate what the amount of coal would have been had the furnace been operated on single-ladle heats, in which case the product would have been reduced one-fourth and the amount of coal increased one-third. Furnace C averages slightly more than 1,000 tons of product weekly, so the product would have been 750 tons, and the coal increased one-third would have been 729lbs. per ton of steel. That is, instead of 1,000 tons of steel, with a coal consumption of 547lbs., on double-ladle heats, we should have 750 tons of steel, with a coal consumption of 729lbs. on single-ladle heats.

Bearing in mind the arguments that were advanced in explanation of the increased product of large heats, the use of pig iron with an average content of 0·70 per cent. phosphorus and 0·70 per cent. silicon, with considerable quantities of lower-grade iron as cheapeners, together with the miscellaneous scrap that the market affords, 729lbs. of coal cannot be considered excessive for eastern practice, particularly covering a period of 22 weeks, so that it is probable a saving of one-fourth is not far wide of the mark. With larger regenerators it is likely a still further saving might be effected.

What has been said in regard to labour and fuel should also apply to repairs. That is, in a given period the wear and tear will be about the same, regardless of the size of the heat or of product. In the run of 22 weeks, the total product from furnace C was 24,298 gross tons, and the repairs that followed, including roof, linings, checkers, cost of brick, bricklaying and common labour, was a fraction less than 6d. per ton.

Having discussed the increased product and economies resulting from the two-ladle practice, what are the objections likely to be raised against this method of steel-making? Probably the first would be the risk of handling such large quantities of steel and the possible consequences in case of accident. In reply, it may be said that in modern open-hearth practice, when linings have been increased in thickness, partly to overcome excessive radiation and partly to prevent accidents, break-outs rarely occur, and as double-ladle practice requires only one-half the usual number of heats to produce the same tonnage, it is evident that that risk, whatever it is, has been cut in half. It may be imagined that serious trouble might result from the chilling of a heat in the furnace, as occasionally happens when the roof falls in. I confess that the first instance of this kind was viewed with some apprehension. It occurred on furnace B, when a charge of 335,000lbs. was melted; the roof from hip to hip fell in. This happened at 8 a.m. on a Saturday, and during the next day the roof and lining were replaced. Gas was turned in at 5-30 a.m. Monday, and the heat was tapped at 10 p.m. Tuesday, yielding 139 gross tons of ingots. A similar experience occurred another time, but in neither case were any difficulties presented other than would be encountered in smaller heats. The divided spout and controller have at all times worked satisfactorily, and no trouble has been experienced in dividing the steel, although occasionally one ladle may receive more than the other, but generally both ladles are evenly filled.

Another objection that might be raised is the difficulty the mills may have in taking care of the product in large units, but a little consideration will show that when mills are provided with sufficient soaking pit capacity, it makes but little difference. If the product is supplied from large furnaces there will be fewer heats, whereas if supplied from smaller furnaces there must, necessarily, be more furnaces, and a largely increased number of heats, frequently causing what millmen call bunching of heats, that is, when several tap together or in close succession. That the large heats are not objectionable to the millmen is evidenced by the interest with which the tapping hours of the large furnaces are followed.

As to the quality of the steel, it may be said very positively that there is no apparent difference from that made in smaller amounts. The chemical analysis, the physical tests, and fabrication of hundreds of thousands of tons would surely have detected any difference had such existed.

Uranium. —The metal uranium is obtained principally in the mineral pitchblende, which consists almost entirely of oxygen and uranium. Although from the time of its discovery the metal has, says the "Journal of the Royal Society of Arts," always commanded a high price, yet, owing to the comparatively small field in which it could be employed, the output of uranium ores was necessarily limited in order to maintain the market. The sources also of its supply have not been plentiful, but now search is being made in different parts of the world, particularly in Cornwall, for pitchblende, which, in order to procure radium, must be had at whatever cost. The manufacture of radium from pitchblende does not interfere with the simultaneous production of uranium oxide, and, having regard to the large quantity of pitchblende necessary to produce a very small quantity of radium, it should follow that the supply of uranium will be greatly increased. This increase in the supply will tend to reduce the market price, and by so doing would encourage a demand for its practical employment. As an illustration, it may be stated that uranium is one of the best-known conductors of electricity extant, and a reduction in price would inevitably increase its use in electrical construction. Uranium mixed with steel is said to form an alloy of high quality, so that when its supply can be maintained in regular quantities, it would obviously be utilised in the manufacture of ordnance, for fine sword steel, and for other purposes of a similar character.

MILL SCALE AS A CAUSE OF THE PITTING OF STEEL PIPES.*

BY GEORGE C. WHIPPLE AND MELVILLE C. WHIPPLE.

STEEL seems destined to come more and more into use as a material for the construction of water conduits of certain size. For small pipes, say up to a diameter of about 3ft., cast iron has proved most satisfactory and economical. As the size increases above this point, cast iron meets a formidable competitor in steel, for although this metal costs more than cast iron, it is stronger and the pipe may be thinner. The use of steel is increasing and it would increase more rapidly if engineers did not fear that corrosion would limit the life and perhaps cause the failure of the pipe line. Cast iron has been tried for many years and experience has shown that it has a long useful life, that may be depended upon. Some wrought-iron pipes also have lasted well. Steel pipes have been used for a shorter period. In general they too have retained their useful life, although in some cases, where they have been exposed to exceptionally severe conditions, they have given trouble.

A number of steel pipe lines have developed leaks, due to the corrosion of the metal in spots, that is, to pitting. In this respect steel appears to differ from wrought iron, over the surface of which the rusting is more uniform. In fact it is this tendency to pit that engineers chiefly fear. Steel pipes almost never fail completely by breakage, as cast-iron pipes sometimes do; they merely leak through the small holes or pits produced by corrosion, so that failure would come about as a gradual process. Nevertheless, leaks are always undesirable, and many leaks, or a large leak, may be serious.

The general subject of the corrosion of steel has been carefully considered during the last few years and the relative advantages of different grades of steel and iron have been much discussed by engineers, chemists, and manufacturers. Some have claimed that wrought iron and steel were equally durable; some have claimed decided advantages for that form of mild steel known as American ingot iron, on account of its low manganese content and the general resemblance of its chemical analysis to that of wrought iron; while some have claimed that the presence of small amounts of copper in steel tended to make it resist corrosion.

In these discussions the importance of one factor has been very largely overlooked, namely, that of the mill scale, and as far as the use of steel for pipe lines is concerned, attention has been diverted from an important element of the problem. Although it is generally accepted by text book writers that pitting is closely connected with the presence of mill scale and that steel from which mill scale has been removed does not pit, the salesmen of the steel companies and even the chemists themselves have much to say about the absence of manganese and the presence of copper, and very little to say about the nature of the mill scale or whether this scale is or is not affected by the purity of the metal. It is to call attention to this neglected phase of the subject that the present paper has been prepared.

In November, 1911, E. A. Fisher, City Engineer of Rochester, N.Y., requested one of us to undertake an investigation to ascertain the relative merits of steel, American ingot iron and wrought iron, for the construction of a 66in. sewer outlet 9,000ft. long into Lake Ontario. This pipe is to carry the effluent from sedimentation tanks through which the sewage of the city is to be passed before being discharged into the lake at a point 7,000ft. from the shore. Samples of steel, wrought iron, and ingot iron were secured, as well as samples of steel containing known amounts of copper.

At the beginning a few simple immersion tests were made. Samples of the steel and iron were placed in jars of distilled water, tap water, salt solutions, solutions of chloride of lime, dilute acids, strong acids, &c., and observations and analyses made to determine the relative amounts of corrosion of the different samples. The results were of some interest, as noted below, but practically speaking it was found that they could not be relied upon to tell which metal would act best when submitted to the conditions expected. The immersion tests in tap water and dilute solutions progressed too slowly, while the use of strong solutions failed to reproduce in the laboratory the conditions that would be met in actual practice. Difficulties also arose in controlling the oxidation of the iron in the solutions after it had been dissolved in the ferrous condition. This was influenced by the volume of the solution used, the ratio of the volume to the surface of water exposed to the air, and several other factors, as Friend has well shown in his recent book on "The Corrosion of Iron and Steel."

Finding that the ordinary accelerated tests, using strong acids, were unreliable so far as the problem at hand was concerned, a different kind of accelerated test was tried, namely, one in which corrosion was stimulated by a current of electricity; that is, an electrolysis test. This was not employed for the purpose of observing those phenomena of corrosion that ordinarily occur when stray currents from high voltage electric lines find their way to a pipe line or other steel structure. On the other hand, the currents employed were much stronger than would be set up in a pipe line by galvanic action, and so did not reproduce the actual conditions of service, but they enabled corrosion to take place in natural water and weak dissociated solutions under conditions similar to those that would be found in the pipe line carrying sewage. It was thought that this test would also show the manner of corrosion, as distinguished from the total amount of corrosion, better than the acid tests, and inasmuch as the real question at issue was one of pitting, and not one of general rusting, the electrolysis test seemed to be a more reliable one for the case at hand.

The results of the application of this test to various samples of steel showed clearly that mill scale has a marked influence on the uniformity of corrosion and the formation of pits. This suggested possible differences in the electrical condition of the mill scale on the different samples of steel submitted to us, and an investigation of this feature was also undertaken.

In the first experiment strips of steel A, ingot iron B, and wrought iron C, as received, were put in separate beakers containing distilled water and allowed to stand at room temperature (70° Fah.). The distilled water contained 3·5 parts per million of CO_2 and was saturated with oxygen. After 24 hours the water in the beaker that contained the ingot iron had less colour than the other two and analysis showed that it contained less iron.

	Steel. A	Ingot iron. B	Wrought iron. C
Area of metal wetted, sq. cm.	23	22	22
Quantity of water, cc.	370	375	395
Iron in water, mg. per litre ..	45	14	36

Samples of steel A, ingot iron B, and wrought iron C were next placed in beakers containing distilled water and tap water, and allowed to stand for various periods of time, during which the appearance of the plates was noted and analyses of the water made to determine the amount of iron present in the ferrous and ferric condition. Variations in the conditions were secured by using hot and cold water and by comparing strips of steel from which the mill scale had been removed with similar strips with the mill scale left on except at the edges.

Detailed records of these experiments were kept, but the results do not warrant publication, as they were so erratic that it was evident that all of the necessary conditions of the experiment had not been properly controlled. Suffice it to say that all three metals rusted badly in all of the experiments, and that such differences as were noted between the different metals were due more to experimental errors than to the character of the metals themselves.

Generally speaking, the rusting was slightly greater in the case of the metals from which the mill scale had been removed, than in the cases of the metals on which the scale had been left, but in this comparison the differences were somewhat less with the wrought iron than with the steel or ingot iron. At the start, the mill scale on the steels appeared to exert a slight protective action, but after a few days this disappeared. On the whole, the ingot iron showed somewhat smaller losses of iron than the other metals, but this was not true in all of the experiments, and the differences were never large.

When two plates of iron are immersed in water and connected with a battery in circuit, a current of electricity will pass through the water from one plate (the anode) to the other

* Abstract of paper read before the International Chemical Congress.

(the cathode), and iron will be dissolved from the anode; in other words, the anode will corrode. If the plate forming the anode is uniform in composition, the corrosion will be uniform over its surface, and the loss in weight will be proportional to the current density. If the anode is not homogeneous in character, the density of the current will not be uniform over the plate, and the corrosion will be greater at some spots than at others. Thus no corrosion at all will occur over areas where some such insulating material as coal tar has been spread, but will occur in greatest degree where the raw metal is exposed.

The mill scale that is formed upon the surface in the manufacture of steel differs in chemical composition from the metal beneath it, being composed largely of iron oxides, together with some slag, and it is to be expected that its electrical resistance would be different. Moreover, the mill scale commonly occurs, not as a sheet of uniform composition and thickness, but as a series of flakes or scales (hence its name), sometimes overlapping and varying greatly in thickness. This is often evident to the eye, but may be better observed by the use of a lens. Hence, when a sheet of steel covered with mill scale is used as the anode, it might be naturally expected that the current density would vary and that the corrosion of the metal would occur, not uniformly, but in spots. Conversely, if the corrosion produced by passing a current of electricity between electrodes is irregular, it may be inferred that the scale is not homogeneous in thickness or quality; and, further, that if different plates act differently when submitted to such a test, the inequality of the character of the scale will be measured by the irregularity of corrosion.

The electrolysis test serves to indicate the manner in which plates corrode rather than the amount of the corrosion. Inasmuch as it is the pitting with which the water-works engineer is chiefly concerned, this form of accelerated test appears to have some advantage over immersion tests in which strong corrosive acids are used. In these strong acids the action is essentially a chemical one, but in the dilute solutions used with the electrolytic test, the strict chemical action is subordinated to the electrolytic form of corrosion. This test, therefore, more nearly approaches the conditions of natural corrosion in water.

It has frequently been observed that with the ordinary acid tests the purer forms of metal show the smaller losses. This is a strict chemical action in which the mill scale, as well as the iron, is dissolved away. With the electrolysis test, however, the purity of the metal itself exerts less influence, and the scale remains for a longer period of time to become an important factor, as it does in actual service.

According to the electrolytic theory of corrosion, the solution of the iron is brought about by the action of currents that are set up between different particles of the metal that have different electrical potentials, as for example, between the pure metallic iron and various impurities such as carbon, manganese, slag, &c. This has been illustrated by Walker, Cushman, and others by the use of the ferroxyl indicator. Purity and homogeneity, therefore, tend to diminish corrosion. It is believed that pits in steel occur at points where for some reason or other there are particles that have greater differences of potential from that of the metallic iron or the mill scale than are found elsewhere on the sheet. Possibly this may result from segregation of the impurities during the cooling of the ingot; possibly it is due to the effect of rolling, cooling, and other treatment the mill scale undergoes. It is known, at anyrate, that differences of potential exist between iron and its oxides, and it seems reasonable to believe that this is a very important cause of pitting, perhaps the most important factor of all.

It seemed to us, therefore, that a study of the potential differences between the mill scale at different points and the raw metal beneath might throw light on the relative liability to pitting of the various metals submitted to us for study. On account of the difficulty of making the necessary measurements with the samples immersed in water, the simple method was adopted of connecting the raw metal of a sample with its mill scale by means of wires, and placing a very sensitive galvanometer in the circuit, the two contact poles being the rounded ends of No. 18 copper wire. The galvanometer used was sensitive to less than one ten-millionth of an ampere. It was found that when both poles were put in contact with raw metal, no current could be detected, but that when one pole touched the raw metal and the other pole touched the scale on a piece of steel plate, a noticeable current was set up, which in some cases amounted to nearly one-millionth of an ampere. Usually the current in the galvanometer circuit was from the scale to the metal, and in the sample from the metal to the scale, that is, in the direction which would tend to make the iron dissolve. Occasionally, however, the current was in the other direction. On the steel plates the currents sometimes differed greatly at points only one millimetre apart; more often, however, there were areas where the current was relatively high, and others where it was relatively low. Very slight currents found in the case of wrought iron and cast iron indicated a great homogeneity of the scale, or less difference of potential between it and the metal. On the whole, it may be said that the index of corrosion uniformity as determined by the galvanic survey of the scale, appears to give a fair measure of the probable liability of the surface of the metal to corrode in an irregular manner, that is, to pit.

That manganese, sulphur, and some other impurities likely to be found in steel stimulate its corrosion is the conclusion of a number of observers. This is particularly true if these impurities are irregularly distributed throughout the mass of the metal. It is unnecessary to review the theoretical reasons advanced for this belief further than to say that they are based on the electrolytic theory of corrosion, and deal with the changes in conductivity and resistance produced within the metal by these impurities. It has been claimed that some other metallic elements when present in small quantities, have an opposite effect upon corrosion; that is, that they retard action. Chief among these is copper. Campbell* says that copper occurs as an impurity in many steels, particularly that made by the Bessemer process, and may be present to the extent of 0·3 to 0·5 per cent.

Opinion seems to be divided in regard to the effect of copper in retarding corrosion. There is evidence to show that it materially decreases the solubility of steel in sulphuric acid, but the question arises as to its effect upon the electrical properties of the steel. Sang† states that the depolarising effect of the electro-negative metals, such as copper and lead, might be expected to hasten the rusting of iron or steel. If copper protects, and if steel ordinarily contains as much copper as Campbell has stated, then it is rather surprising that the copper steels have not given better service. The samples tested (J, K, and L) contained 0, 0·23 per cent. and 0·53 per cent. of copper, respectively.

The use of copper steel having been suggested for the Rochester pipe, some experiments were undertaken to determine its advantages, if any, for this service. These included immersion tests, electrolysis tests, and galvanic surveys. Strips of the metal 2½in. by 8in. were buffed and cleaned of dirt and grease, weighed and placed in glass trays, supported upon four ⅛in. pieces of the same metal; 450 cc. of 25 per cent. sulphuric acid, enough to completely immerse the strips, was then poured into the tray. Twice during a period of 24 hours this acid was renewed and the solution was stirred occasionally. At the end of 24 hours the plates were removed, washed, dried, and weighed. In the case of sample J, which contained no copper, the action had been violent, as evidenced by the evolution of hydrogen and the bright etched surface of the plate. Sample L, which contained the most copper, showed the least action, as far as surface appearance indicated. The following losses in weight were obtained. The loss in weight is seen to be much greater in the steel that contained no copper than in the other two.

Immersion Test with 25 per cent. Sulphuric Acid.

Sample.	Per cent. of copper.	Loss of weight in grams.	Area exposed in Sq. Cm.	Loss of weight in grams per Sq. Cm.
J	0	27·0	307	0·0880
K	0·23	5·4	270	0·0200
L	0·53	5·1	258	0·0198

* "Metallurgy of Iron and Steel," p. 358.

† Sang, "Corrosion of Steel," p. 37.

The effect of a dilute sulphuric acid solution was also tried. For this purpose an N—50 solution of acid (*i.e.*, about 0·1 per cent.) was used, the cleaned plates being placed in 2-quart glass jars and covered with the acid. After 26 days the following losses of weight were found:—

Immersion Test with $\frac{N}{50}$ Sulphuric Acid.

Sample.	Per cent. of copper.	Weight in Grams.	Area exposed in Sq. Cm.	Loss in grams per Sq. Cm.
J	0	3·00	234	0·0128
K	0·23	2·90	247	0·0117
L	0·53	3·15	231	0·0136

These results were in marked contrast to those in which the stronger acid was used, as they showed only slight differences between the losses from metals containing different amounts of copper.

Immersion tests were also made using sodium chloride solutions of two strengths, namely, 0·3 per cent. and 3 per cent., the latter having a salinity about equal to that of sea water. The losses in weight after 26 days were as follows:—

Immersion Tests with Salt Solutions.

Sample.	Per cent. of copper.	Lost of weight in grams per Sq. Cm.	
		3% solution.	0·3% solution.
J	0	0·0015	0·0013
K	0·23	0·0015	0·0019
L	0·53	0·0019	0·0021

The general results of the immersion tests go to show that where the action is emphatically a chemical one, as in the case of the strong acid test, the presence of copper tends to reduce the action; but where, as in the tests with weak dissociated acids and salt, the electrolytic form of corrosion predominates, copper does not reduce corrosion, but on the other hand, tends slightly to stimulate it.

From the tests made it was concluded that the presence of small amounts of copper in steel, while they may retard corrosion by strong acids, do not serve to protect the steel against corrosion in weak acid solutions or in ordinary water. The presence of copper does not materially alter the electrical conditions of the scale, and does not, therefore, protect the metal against pitting.

The samples of American ingot-iron plates tested were found to have an index of corrosion uniformity somewhat higher than that of ordinary steel plates, with or without copper, but lower than that of wrought iron. So far as failure by pitting is to be feared, therefore, the ingot iron may be regarded as somewhat better than steel; but probably not enough better to justify any great difference in cost. Exposed to severe acid corrosion, ingot iron is probably more serviceable than steel, but under ordinary conditions of corrosion in soil or water, it has only a slight advantage over steel.

Wrought iron has a very much higher index of corrosion uniformity than steel or ingot iron and is much less likely to pit. This seems to be in accord with experience. Under conditions of severe chemical corrosion, sufficient to remove the mill scale and silicates, or under conditions of atmospheric corrosion, when the electrolytic form of corrosion does not predominate, there is probably little difference between the two metals.

A partial removal of the mill scale tends to increase corrosion as it gives opportunity for electrolytic action between the scale and the raw metal. Scale becomes chipped off in handling and in fabrication. The complete removal of the mill scale from steel plates increases its index of corrosion uniformly from about 50 to nearly 100 and this reduces materially the danger of pitting. The electrolysis tests made with steel plates, from which the mill scale was removed, did not show pitting in a single instance. Scale removal appears, therefore, to be a secure method of protection against pitting. To some extent it has been practised, the mill scale being removed by pickling in acid, by sand blasting, &c. These processes unfortunately are expensive, but may be justified under some conditions. Steel of ordinary quality with the mill scale removed will probably withstand pitting better than the more expensive ingot iron and copper steels, and just as well as wrought iron itself.

It is possible that some method may be found to modify the mill scale during manufacture so as to make it more uniform or improve its electrical condition, or make it more easily removable. It certainly seems as if the next step in advance in steel manufacture lies in securing a better control of the character of the mill scale. An extended study and series of experiments on the formation, composition, and electrical properties of scales produced at different temperatures might determine the conditions that must be controlled to produce a satisfactory scale. If a satisfactory scale cannot be obtained, the only apparent remedy for pitting is scale removal.

It is the opinion of the authors that the experiments and observations outlined warrant the following general conclusions relative to short time tests for corrosion, and to the part played in corrosion by mill scale.

(1) Accelerated corrosion tests of iron and steel plates made by immersion in strong acid solutions are of little value as indicating the probable corrosion of the metals in water under conditions of actual service.

(2) Accelerated tests made in running water by the use of a current of electricity give results that indicate the manner in which the plates will probably corrode in service; that is, whether by pitting or by general corrosion.

(3) When steel pipe lines fail, they do so by the formation of numerous pits that ultimately form holes and cause leaks. An important factor in the formation of pits, commonly recognised but by no means fully appreciated, is the mill scale.

(4) Steel plates that pit badly under the electrolysis test when the scale is left on do not pit after the scale has been removed.

(5) A galvanic survey of the mill scale, made by determining the current that will pass through a sensitive galvanometer placed in the circuit of wires that connect the mill scale with the metal beneath, gives results that differ materially for wrought iron and steel, and from which an index of the uniformity of corrosion may be calculated that bears a general relation to the liability of the metals to form pits.

(6) The electrolysis tests and the galvanic survey show that wrought iron has a less tendency to pit than steel, and that American ingot iron is intermediate between the two, but resembles steel more nearly than it does wrought iron.

(7) Steels containing copper differ but slightly among themselves and from steel that contains no copper, in their tendency to form pits.

(8) To protect steel or ingot iron against failure by pitting, the best remedy is the removal of the mill scale. Efforts should be made to reduce the expense of doing this, or to modify the character of the scale during its manufacture. This appears to be the direction in which future improvements in the manufacture of steel plates for pipe lines should lie.

Furnace for Electric Smelting of Nickel.—Experiments with a new type of nickel refining furnace have, we learn, been in progress for the last four months at the Technical High School at Trondhjem, and are now completed. They were made with the object of finding a satisfactory type of furnace for the reduction of garnerites ("garneriter") from Egypt and New Caledonia, which are difficult to smelt, and the results are stated to have proved satisfactory.

New Express Goods Engines for the Great Northern.—There are now under construction at the works of the Great Northern Railway 10 express goods locomotives of the 2-6-0 type. These engines, which have been designed by Mr. H. N. Gresley, locomotive engineer to the company, will be fitted with superheaters, and will have outside cylinders 20in. by 26in., and coupled wheels 5ft. 8in. diam. The valves will be operated by Walschaert's valve gear. Of the total heating surface of 1,420 sq. ft., 981 sq. ft. will be furnished by the tubes, 137 sq. ft. by the firebox, and 302 sq. ft. by the superheater. The grate area will be 24½ sq. ft., and the working pressure 170lbs. per square inch. The maximum weight in working order will be 61 tons 14 cwts., of which 51 tons 14 cwts. will be on the coupled wheels.

THE CENTRIFUGAL BLOWER FOR HIGH PRESSURES.*

BY HENRY F. SCHMIDT.

In presenting the following notes, the writer does not claim originality, but offers the material simply as a collection of the essential elements of blower design in convenient form for reference. The centrifugal blower for high pressures has suffered through the same lack of knowledge in regard to its possibilities as that which affected the introduction of the centrifugal pump for high pressures and high shaft speeds. A general impression was created among engineers from early experiments that centrifugal pumps and blowers were adapted for handling only large volumes against low heads, and with comparatively low efficiency. This, however, has been shown to be an incorrect statement in the case of centrifugal pumps, and it is also untrue in respect to centrifugal blowers. With proper methods of construction of the rotating parts and due regard to the theory involved, it is possible to build blowers for practically any capacity and pressure with efficiencies ranging from 65 per cent. to 80 per cent. or more, the higher efficiency, of course, being for the larger volumes handled.

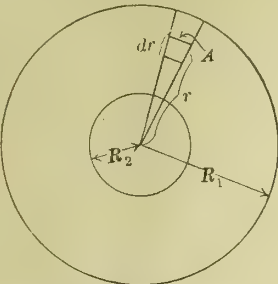


FIG. 1—PRESSURE WITHIN THE IMPELLER.

Before an intelligent conception of the characteristics of centrifugal blowers can be obtained it is necessary to examine the theory, which is not only simple but extremely interesting. The first problem to be considered is the pressure created within the impeller due to the centrifugal force acting on the volume of air between the blades of the fan. This can be done as follows: In Fig. 1, imagine a tube extending radially from the shaft to the circumference, and assume the area of this tube to be A square feet. If an infinitely thin lamina of this tube be taken, the weight of the air contained in it will be $\rho A dr$ where ρ is the density of the air at that point. If this lamina is taken at radius r, then the centrifugal force acting on this small mass of air will be

$$dF = \frac{\rho A dr \mu^2}{gr} = \frac{\rho A \ (2\pi)^2 r N^2 dr}{g}$$

in which N = revolutions per second. If the compression in the blades is adiabatic, the volume of a pound of air at any point is found from the relation $pv^\gamma = p_1 v_1^\gamma$ or

$$v = v_1 \left(\frac{p_1}{p}\right)^{\frac{1}{\gamma}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

But since the density is inversely proportional to the volume

$$\frac{1}{\rho} = \frac{1}{\rho_1}\left(\frac{p_1}{p}\right)^{\frac{1}{\gamma}} \text{ or } \rho = \rho_1 \left(\frac{p_1}{p}\right)^{-\frac{1}{\gamma}}$$

Now also dF must equal the difference in pressure between the two sides of the lamina (dr) or $dF = Adp$. Hence, substituting the value of dF and p

$$dF = Adp = \frac{\rho_1 \left(\frac{p_1}{p}\right)^{-\frac{1}{\gamma}} A \ (2\pi)^2 N^2 r dr}{g}$$

Transposing $\rho_1 \left(\frac{p_1}{p}\right)^{-\frac{1}{\gamma}}$

$$\frac{1}{\rho} p_1^{\frac{1}{\gamma}} p^{-\frac{1}{\gamma}} dp = \frac{(2\pi)^2 N^2 r dr}{g}$$

Integrating between $\gamma = 0$ and $\gamma = R$, and p_1 and p_2,

$$v_1 p_1^{\frac{1}{\gamma}} \int_{p2}^{p1} p^{\frac{1}{\gamma}} dp = \frac{(2\pi)^2 N^2}{g} \int_0^R r dr$$

which gives

$$v_1 p_1^{\frac{1}{\gamma}} \frac{\gamma}{\gamma - 1} \left[p_1^{\frac{\gamma-1}{\gamma}} - p_2^{\frac{\gamma-1}{\gamma}}\right] = \frac{(2\pi)^2 N^2 R^2}{2g} \quad \ldots \quad (2)$$

* Paper read before the American Society of Mechanical Engineers.

But the first term of this equation is the work done in adiabatic compression or expansion, and the second term equals $\frac{\mu_1^2}{2g}$, hence the work done in the impeller is equal to that required to accelerate the air from rest to the velocity of the blade tips. Since, however, if the radial velocity is very small, the final tangential velocity of the air is μ_1, it is evident that one-half of the total work done on the air by the blades will be expended in accelerating it to a velocity equal to that of the blade tips, and the other half in compressing it to a pressure P_2. Hence unless the final velocity of the air is reduced by converting the kinetic into potential energy, the maximum efficiency of a centrifugal compressor, neglecting all losses, can be but 50 per cent. It is evident, therefore, that some efficient means must be provided to convert the kinetic energy represented by the final velocity into potential energy represented by an increase in pressure. This can be done in one of three ways: (1) By means of diffusion vanes placed around the periphery of the impeller; (2) by the use of a volute of proper design; (3) by a diffusion tube or inverted nozzle attached to the outlet of the compressor.

The first of these methods is probably the most efficient at approximately the designed capacity if properly constructed, but is inefficient at large and small discharge rates. The additional cost of construction is also one of its disadvantages. Theoretically and practically, the second method is the most efficient over a wide range of loads, and has, if well designed, an efficiency of 65 per cent. to 90 per cent. It is, however, more costly to construct than the third method. Diffusion tubes attached to the discharge, though the cheapest to construct, have only cheapness and compactness to recommend them, and cannot be used on the intermediate stages of multi-stage compressors. The reason for the inefficiency of diffusion tubes is that serious eddies are formed in them due to the varying pressures at different sections of the discharge opening. The latter results from the fact that the air farthest from the shaft is compressed the most and has a higher velocity, which causes eddies.

From an examination of equation (2) representing the increase of pressure or work in foot-pounds per pound of air in the impeller, it is evident that the most peculiar characteristic of the centrifugal blower is that for a fixed number of revolutions per minute, or tip speed of the impeller, the work done remains constant so long as the volume entering the blower remains constant. It will be noted that in this respect a centrifugal blower departs entirely from the piston compressor in that the volume discharged depends upon the pressure against which the blower is working, whereas in the

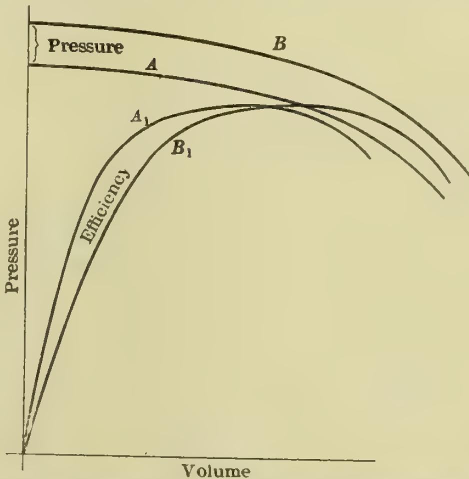


FIG. 2.—PRESSURE AND EFFICIENCY CURVES, CENTRIFUGAL BLOWER.

piston blower for a fixed number of revolutions per minute the volume remains practically constant, the pressure of discharge varying according to the resistance placed in the discharge.

It will be noted that the work done in a centrifugal blower varies directly as the square of the tip speed, or if the diameter of the impellers is fixed directly as the number of revolutions per minute, and the capacity almost directly as the number of revolutions per minute. The result is that the

pressure and efficiency curves for a change in the number of revolutions per minute vary somewhat from the manner shown diagrammatically in Fig. 2. The point to be noted particularly in regard to Fig. 2 is that the maximum efficiency obtained is practically independent of the number of revolutions per minute, since all the losses in the blower vary directly as the cube of the number of revolutions per minute, as does also the total work done per pound of air. Consequently, the losses bear the same relation to the total input at a small number of revolutions or at a low pressure discharged

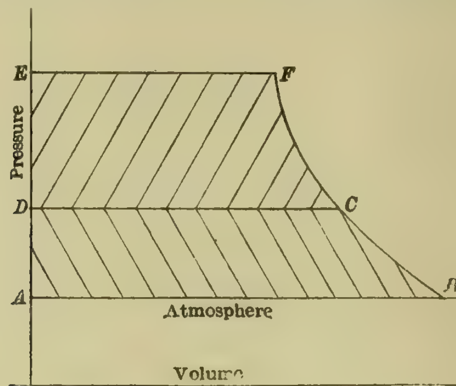


FIG. 3.—DIAGRAM OF WORK DONE BY TWO IMPELLERS IN SERIES.

against, as they do for a higher number of revolutions and higher pressure. For this reason the efficiency curve characteristic remains the same for changes of speed, but the point of maximum efficiency shifts to a smaller volume with decrease in the number of revolutions per minute.

As the work done per pound of air is independent of everything except the tip speed and the volume of the air entering the impeller, it is evident that the air discharged from one impeller may be supplied to a second impeller, which will add the same number of foot-pounds of work per pound of air to it, thus increasing the pressure by adding that created by the first impeller to that created by the second. The effect of this will be seen by examining Fig. 3, in which the area $BADC$ represents the work done by an impeller compressing from atmospheric pressure to a pressure D. Where the air is discharged into a second impeller doing the same amount of work or the area as represented by the area $CDEF$, which is equal to the area $BADC$, it should be noted that, owing to the decrease of volume with increase of pressure, the actual difference of pressure created in the second impeller is greater than that in the first, so that high pressures can

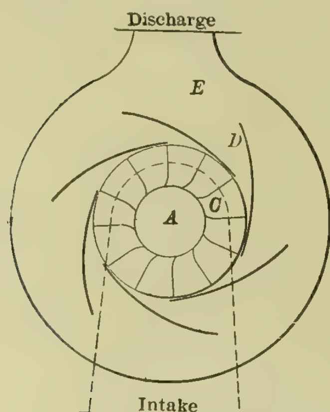


FIG. 4.—GUIDE VANE BLOWER.

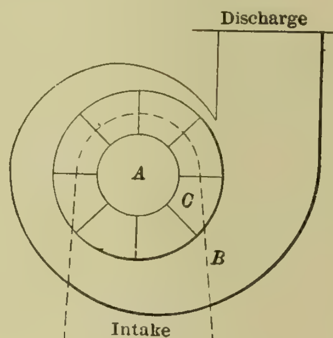


FIG. 5.—VOLUTE BLOWER.

be attained with a comparatively small number of impellers or stages in series. The efficiency of such a combination of impellers placed in series is exactly the same as though each impeller were an independent unit, the total efficiency being the same as that of the individual stages.

Figs. 4, 5, 6, and 7 show diagrammatically the construction and characteristics respectively of the guide vane and volute types of blower. As will be noted by examining Fig. 4, the guide vanes consist of a number of curved vanes surrounding the impeller or rotor and pointing in the direction of rotation. Since the air discharged from the impeller enters the diffusion vanes at the narrowest portion at a high velocity, and leaves at the point of greatest cross-section with a greatly reduced velocity, the difference in kinetic energy between the point of entrance and exit is partly utilised in increasing the pressure of the air and partly in eddies and friction, the latter part reappearing in the form of heat. The characteristic of this type of blower is seen in Fig. 6, which shows that the pressure at first increases as the volume of discharge increases, until it reaches a maximum, after which the pressure again falls off, and it will also be noted that at constant discharge (and constant revolutions per minute) the pressure does not remain constant, but is continually fluctuating between limits, as shown by the shaded lines, which usually represent about 10 to 15 per cent. of the total pressure created. The reason for this will be understood by examining Fig. 8.

For the sake of illustration, instead of assuming the air to leave the impeller, imagine it to issue from a nozzle through which the air is supplied at a pressure P_1 and expands to a pressure P_2 such that the velocity at the mouth of the nozzle is exactly equal to the velocity with which it leaves the tips of the impeller blades and enters the guide vanes. Further, in place of the guide vanes, assume a straight diffusion tube discharging into a receiver R. The pressure in it is controlled by means of a valve or other device. Hence, from the assumptions made, the diffusion tube, when supplied with air as stated, is an exact equivalent of the guide vanes in the blower shown in Fig. 4. Now, since the area of the diffusion tube increases, the velocity of the air must decrease, with the result, as previously mentioned, that the kinetic energy is partly converted into pressure, as indicated by the diagram beneath the diffusion tube. The line A_1 is the final pressure

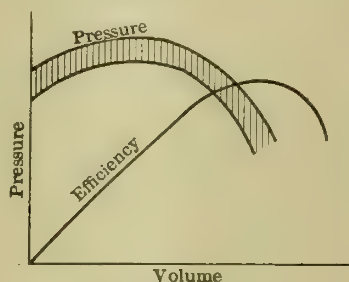


FIG. 6.—GUIDE VANE BLOWER CHARACTERISTICS.

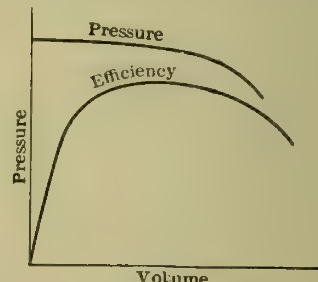


FIG. 7.—VOLUTE BLOWER CHARACTERISTICS.

resulting from the velocity attained by the air in expanding in nozzle from pressure P_1 at A to the back pressure P_2, and the line B_2 represents the final pressure of the air when expanded from the initial pressure B to the final pressure P_2. Now it will be evident from the method in which this velocity conversion takes place that there can be but one pressure of equilibrium for any given velocity with which the air enters the diffuser. Furthermore, if the pressure P_3 in the receiver R is built up to the point where air can no longer enter the inlet of the diffuser, the pressure in the receiver must break down, for with no air entering the diffuser the velocity becomes zero, and velocity conversion is no longer possible. The result of this condition is that in a centrifugal blower fitted with guide vanes, under certain conditions the pressure may break down to the point where the only pressure available at the discharge is that due to the impeller alone, and even with normal rates of discharge there is also a tendency for the diffuser vanes to build up a pressure higher than that in the receiver R, resulting in a constant building up and breaking down of the pressure, as shown in Fig. 9.

The rapidity with which these variations occur depends upon the volume of the receiver space and pipe line into which the blower is discharging. The smaller the receiver volume the more rapid the fluctuations and the smaller their extent. With very large receiver volumes, and especially with a number of such blowers operating in parallel, fluctuations may occur in which the pressure breaks down to that of the impeller alone. To obviate this, it is customary to throttle such blowers at the intake so as always to operate them below the lower pressure line in Fig. 6, thus avoiding the fluctuations of pressure.

The fact that no pressure is created by the diffuser tube when no air is being delivered is the reason for the increase of pressure with increase of volume delivered up to a certain point, beyond which the diffusion tubes are no longer of sufficient exit areas to reduce the final velocity to the necessary point, which in addition to the increased friction at the higher velocities causes a dropping off of the pressure line, as shown in Fig. 6. The result of this is that the efficiency curve rises

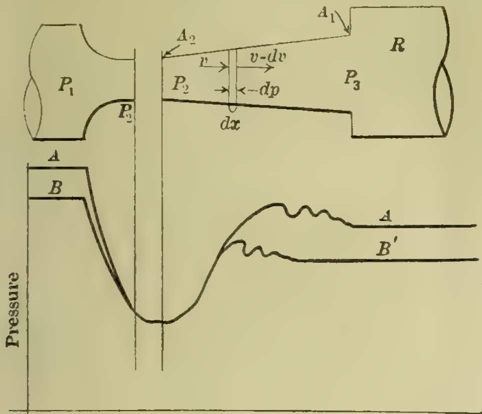


FIG. 8.—PRESSURE VARIATIONS, NOZZLE AND DIFFUSION TUBE.

very slowly at first and becomes a maximum over a comparatively very short range, when it immediately begins to drop off very rapidly.

The above actions will be better understood by examining the theory of diffusion vanes, in connection with Fig. 8, as follows: Let the area of the smaller or entrance end of the diffuser be A_2 and the exit area be A_1; also assume that no heat is received by or given up by the diffusion tube, in which case the compression will be adiabatic (though in practice not necessarily isentropic) and the relation between pressure and volume at any point will be determined by the equation

$$pv^{\gamma} = pv_2^{\gamma} \text{ or } v = \left(\frac{p_2}{p}\right)^{\frac{1}{\gamma}} v_2$$

In Fig. 8 consider an infinitely thin section of the tube dx and assume that the pressure at the point the section is taken is p, and the velocity on one side of the section is V, and that the velocity on the other side is $V - dV$. Also assume that the mass of air within the section considered meets with

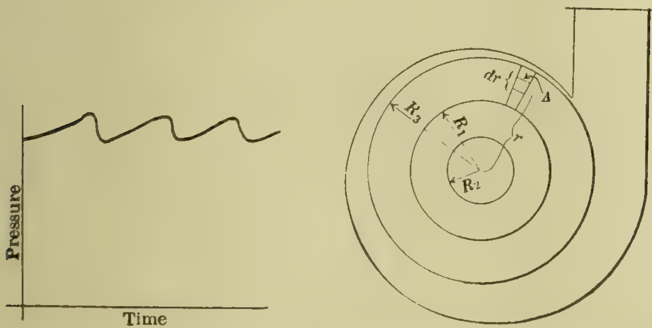


FIG. 9.—PRESSURE VARIATIONS, GUIDE VANE BLOWER.

FIG. 11.—PRESSURE DIAGRAM IN A VOLUTE BLOWER, WITH A FREE VORTEX.

such a resistance as will be produced by the force $dF = Adp$, A being the area of the tube at the section taken.

Now the mass of the air in the section will obviously be $dw = PAdx$. But force is equal to mass times acceleration, hence,

$$dF = \frac{\rho Adx}{g}\,\frac{v-dv}{dt} = \frac{\rho Adx}{g}\,\frac{d^2x}{dt^2}$$

and also

$$dF = Adp$$

Hence equating these two expressions for dF

$$Adp = \frac{\rho Adx}{g}\,\frac{d^2x}{dt^2}$$

but

$$\rho = \frac{1}{v}$$

hence

$$Adp = \frac{Adx}{v_2\left(\frac{p_2}{p}\right)^{\frac{1}{\gamma}} g}\,\frac{d^2x}{dt^2}$$

or

$$g v_2\, p_2^{\frac{1}{\gamma}}\,\frac{dp}{p^{\frac{1}{\gamma}}} = \frac{d^2x}{dt^2}\,dx$$

which may be integrated between V_1 and V_2 and p_2 and p_1, and will give

$$2g\,\frac{\gamma}{\gamma-1}\,RT_2\left[\left(\frac{p_1}{p_2}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] = -\left[V_1^2 - V_2^2\right] \quad . \quad (3)$$

that is, since kinetic energy has disappeared into potential energy the sign is negative. The most interesting part of this equation is that an examination shows that the kinetic energy lost in changing from a velocity V_1 to velocity V_2 is exactly the same as that given up in adiabatic expansion from the pressure P_1 to the pressure P_2. In other words, neglecting friction eddies and shock, for some fixed relation between the velocity of approach and final pressure, as indicated by the

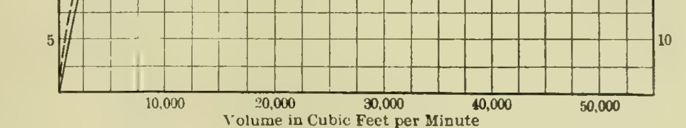


FIG. 10.—CHARACTERISTICS OF TWO BLOWERS UNDER DIFFERENT EFFICIENCY CURVES.

formula, the theoretical velocity conversion efficiency of a diffusion tube is unity, and constant delivery is likewise theoretically possible.

Returning now to the volute blower shown in Fig. 5, which is not fitted with guide vanes, an entirely different characteristic is obtained, the theoretical characteristic of this blower being a perfectly straight line, that is, constant pressure for any delivery, neglecting, of course, the energy put into the air in order to move it through the blower. In this type of blower, as there is no velocity conversion in the volute, the pressure remains the same at all rates of delivery except for the increased frictional resistance with higher velocities and larger discharge rates, which results in a gradual decrease of the pressure as shown in Fig. 7.

However, the most remarkable point in this design of blower is the rapidity with which the efficiency curve rises with increase of discharge rate, and the wide range over which it remains practically constant. Though not plotted to scale, the pressure characteristics and efficiency characteristics shown in Fig. 7 are relatively exact, as found in the two types of blower, the maximum efficiency obtainable in both the volute and guide vane being for both purposes identical, pro-

vided, of course, that both are properly designed; but the point which should be noted particularly is that in commercial operation the value of a blower operating on fluctuating load depends not upon the maximum efficiency obtained, but upon the area under the efficiency curve since this is a true measure of the average efficiency over a range of load. The results from two blowers on actual test are given in Fig. 10, which clearly show the difference in the characteristics and the area under the two efficiency curves.

In order to find the pressure created in a free vortex, assume a tube extending from R_1 to R_3, Fig. 11, of area A,

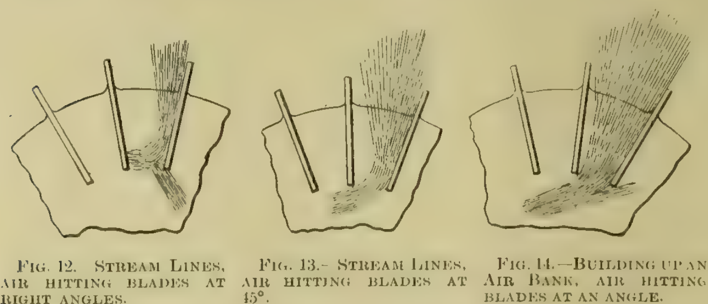


FIG. 12. STREAM LINES, AIR HITTING BLADES AT RIGHT ANGLES. FIG. 13.—STREAM LINES, AIR HITTING BLADES AT 45°. FIG. 14.—BUILDING UP AN AIR BANK, AIR HITTING BLADES AT AN ANGLE.

and take a lamina of this tube of thickness dr at any radius r. Then the centrifugal force acting on this small mass of air will be

$$dF = Adp = \frac{\rho A dr \mu^2}{gr} \text{ or } vdp = \frac{dr\mu^2}{gr}$$

But μ is inversely proportional to the radius, hence the velocity μ at any point will be $\frac{\mu_1 R_1}{r}$ where μ_1 is the tip velocity of impeller. Substituting the value of μ,

$$vdp = (\mu_1 R_1)^2 \frac{dr}{gr^3}$$

and integrating between the limits p_2 and p_3 and $r = R_1$, and $r = \infty$

$$\frac{\gamma}{\gamma - 1} 2g\, p_2 v_2 \left[\left(\frac{p_3}{p_2}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] = -\frac{\mu_1^2 R_1^2}{\infty^2} + \frac{\mu_1^2 R_1^2}{R_1^2} = \mu_1^2$$

which shows that for a 100 per cent. conversion efficiency the volute must be of infinite diameter. For any given radius of volute R_3 the work done by the velocity conversion in foot-pounds will be

$$W = \frac{\mu_1^2}{2g}\left[1 - \left(\frac{R_1}{R_3}\right)^2\right]$$

or the velocity conversion efficiency is

$$E = 1 - \left(\frac{R_1}{R_3}\right)^2$$

Now the reason for the statement that the pressure remains practically constant in a blower having a free vortex will be evident from the preceding mathematical demonstration, since it follows that as the pressure created in the vortex is due to the centrifugal force acting on the fluid in the vortex, neglecting friction and eddies, the pressure created must be independent of the volume delivered. This must be true for the further reason that the volume delivered does not enter into the mathematical analysis as a function of the work done, whereas, in the mathematical deduction of the equation of flow (or work done) in a diffusion tube, the volume enters the equation in the expression $(V_1^2 - V_2^2)$.

As previously stated, neglecting friction, the energy transformation taking place in a free vortex remains constant regardless of the volume delivered, even though the delivery is reduced to zero, and likewise the efficiency is for the same reasons constant, independent of the volume delivered. This explains the much higher efficiency of the free vortex blower at partial rating than is obtained in a blower fitted with guide vanes. Further, when the element of friction is considered, the free vortex blower has a considerable advantage over the diffusion vane blower because the surface exposed to friction is very much smaller.

The preceding remarks are not based on theory alone, since the writer has made a large number of tests with pitot tubes and thus verified the above statements. These tests showed that, when properly constructed, theory and practice agree to a surprising extent. In a discussion before the society some time ago the design of the impellers used by the Westinghouse Machine Company was criticised as inefficient because the blades are radial and have no curvature at their inlet ends for picking up the incoming air without shock losses. It has been shown that if the blades of an impeller extend all the way into the centre of the shaft, the work done by compression in the rotor is just one-half of the total work done on the air, the other half being represented by the kinetic energy in the air leaving the impeller with the velocity of the blade tips, that is, energy represented by $\frac{\mu_1^2}{2g}$ per pound.

In actual practice the inner diameter of the blades, or "eyes," is usually about one-half the diameter of the impeller, or, say, just one-half, then the velocity of the entrance edges of the blades is one-half the tip velocity, that is $\mu_2 = \frac{1}{2}\mu_1$. But the total energy put into the air is $2\left(\frac{\mu_1^2}{2g}\right)$ per pound, and since the velocity at the blade entrance is $\frac{1}{2}\mu_1$ the maximum loss from shock, if the air hits the blades at right angles, as in Fig. 12, would be $\frac{(\frac{1}{2}\mu_1)^2}{2g}$ and the percentage loss of the total energy put into the blower would consequently be

$$100 \frac{\frac{(\frac{1}{2}\mu_1)^2}{2g}}{2\left(\frac{\mu_1^2}{2g}\right)} = 12 \cdot 5$$

The preceding is on the assumption that all the velocity of the air relative to the blade is destroyed, which, however, is far from the truth.

Since it is necessary for the air to have a radial velocity in order to pass through the impeller (usually the radial velocity of the air is about one-quarter of the tip velocity, or one-half of the velocity of the entrance of the blades), instead of striking the blades at right angles, it enters the blades about as shown in Fig. 13 at an angle of 45°. Hence, if a total loss by shock of the velocity component perpendicular to the blade is still assumed, the loss at the entrance is reduced from 0·125 of the total energy to about 0·06 of the total energy put into it. However, it is known that when air strikes a surface at an angle, there is a tendency to build up a bank of air, as shown in Fig. 14, and since the flow is continuous, all the energy is not lost by shock. Hence, it is very conservative to estimate the loss at the entrance with radial blades as not exceeding 1 or 2 per cent. This is also verified by the tests which have been made, as it was impossible to find the loss at the entrance because of its being so small compared with the total energy put into the air.

Another reason why the loss is practically nothing in the Westinghouse design is that the inlet of the blowers is made

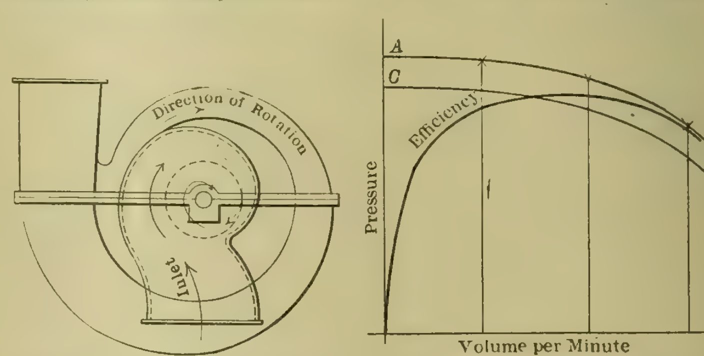


FIG. 15.—INLET OF BLOWER, WESTINGHOUSE DESIGN. FIG. 16.—PRESSURE AND EFFICIENCY CURVES, CENTRIFUGAL BLOWER.

in the form of a volute and forced vortex as shown in Fig. 15, thus causing the air to rotate in the same direction as the impeller before entering the impeller, and the proportions of this volute are so made that at normal load the air enters the impeller blades tangentially without any shock loss whatever.

Since centrifugal blowers for all except the very lowest pressures must run at comparatively high tip speeds, it becomes imperative that the rotor construction shall be of the

very best design possible, and all the stresses in the blades must be radial. Hence a straight radial blade is the only one which can be used except at the very lowest speeds.

No riveted or built-up construction can be satisfactory, and only an impeller of the double-flow type milled out of the solid should be tolerated. Milling the rotor in halves and riveting them together is also a very poor construction, and has only cheapness to recommend it. The disc should be of such section as to give uniform stress throughout, and there should be no hub or hole for the shaft.

(*To be continued.*)

LOCOMOTIVE VALVE GEARS.

A SHORT paper on this subject was recently read by Mr. W. S. Salter before the Northampton Polytechnic Institute Engineering Society. Valve gears in locomotive practice required, he said, careful consideration, because of the confined space in which they had to operate and the high speeds at which they were run. Almost universally the D and piston slide valves were used. Reversing was obtained by altering the position of the valve relative to the ports, and by altering the point of cut-off steam might be economised. To cause this reversing and alteration of cut-off many gears had been designed, but only three had survived in general use. In early engines a single shifting eccentric was used, the driver having to move the eccentric over by hand. Single eccentric gears worked from the footplate were used in 1830. In 1837 double eccentric gears came into use. These were of the "gab" type, *i.e.*, a crocodile shaped jaw was attached to each of the eccentric rods and by engaging the pin on the valve spindle in either backward or forward gab, reversing was accomplished. At this stage the engine could only be reversed when at a standstill and, of course, no expansion could be used.

Stephenson's link motion had been the means of bringing the locomotive to its present efficiency. The motion consisted essentially of two eccentrics, one for forward and the other for backward running. The eccentric rods were connected to the top and bottom of a curved link. A block moved in this curved link, and was attached to the valve rod. By raising or lowering the curved link the valve rod was brought under the control of the backward or forward eccentric, thus causing a reversal in the direction of running. The links were raised either by hand or power. The alteration of lead in the Stephenson's gear being thought unsuitable, Gooche's gear was designed to have a constant lead. The curved link was turned round opposite to that of Stephenson's, and was equal to the radius of the valve rod that was raised and lowered to give the change of cut-off, the curved link being permanently suspended from a freed point. Allen's link motion was also designed for a constant lead using a straight link. The link and the valve rod both moved in opposite directions to produce the reversal of running. Walschaert's gear, the invention of a Belgian, had not been much used in England, but was making headway. It had been used extensively on the Continent and in America. It was well adapted to outside cylinder engines. The motion it gave to the valve was a combination of two movements, one derived from the crosshead and the other from an eccentric. The motion from the eccentric was transmitted through a curved link in which was placed a block, the raising or lowering of which caused the reversing or expansion. Joy's gear also used a combination of movements to give the required travel to the valve. No eccentrics were used. Motion was taken from the connecting rod, and by an oscillating link was transmitted to the valve. The point about which the link oscillated had an up-and-down motion, which was compounded with that from the connecting rod by a curved guide, thus giving the valve its necessary travel. Reversing or notching up was then obtained by altering the inclination of the curved guide.

The Physical Society's Annual Exhibition.—This Exhibition, which is to be held on Tuesday, the 17th inst., at the Imperial College of Science, South Kensington, will be open both in the afternoon from 3 to 6 p.m., and in the evening from 7 to 10 p.m.

PROFIT-SHARING AND LABOUR CO-PARTNERSHIP.

THE Labour Department of the Board of Trade has issued a report on Profit-Sharing and Labour Co-partnership in the United Kingdom. In presenting the report, Mr. George S. Barnes says that profit-sharing was understood to involve an agreement between an employer and his workpeople, under which the latter received, in addition to their wages, a share (fixed beforehand) in the profits of the undertaking. A grant or bonus, therefore, made at the absolute discretion of an employer and not upon any prearranged basis was not a case of profit-sharing for the present purpose. It would be difficult to determine in the less well-organised trades, in which many of the profit-sharing schemes had been started, whether the wages paid were the full current district rates. Labour co-partnership was an extension of profit-sharing, enabling the worker to accumulate his share of profit in the capital of the business employing him, thus gaining the rights and responsibilities of a shareholder. A still further stage was found in some co-partnership schemes which provided for a direct share in the management as well as a share in the profits, one or more seats on the board of directors being reserved for representatives of the workers. The number of profit-sharing schemes in private firms and companies which were now in operation was 133, the number of workpeople employed by the firms having such schemes being about 106,000. The present schemes were the survivors of nearly 300 profit-sharing arrangements, of which 163 had been abandoned. The accompanying table gives particulars of the trades in which profit-sharing schemes have been adopted.

Nature of business.	Total number of schemes.	Number of schemes abandoned.	Schemes existing August 1st, 1912.	
			Number of businesses.	Number of employés.
Building trades	12	9	3	151
Mining and quarrying	6	6	—	—
Metal, engineering and shipbuilding trades :—				
Metal	9	8	1	163
Engineering and shipbuilding	21	17	4	17,336
Textile trades	14	7	7	4,951
Clothing trades	19	12	5	1,637
Transport	3	2	1	173
Agriculture	18	12	6	737
Printing, paper, and allied trades :				
Paper making	5	1	4	794
Printing, bookbinding, &c.	36	25	11	3,389
Woodworking and furnishing trades	10	7	3	169
Chemical, glass, pottery, &c.	22	8	14	15,649
Food and tobacco	31	18	13	6,760
Gas works	34	1	33	28,246
Electricity supply	2	—	2	414
Other businesses	57	30	26	25,620
	299	163	133	106,189

The number of workers who were entitled to share in profits at the end of 1911 (or in 1912 in the case of schemes started since 1911) was 57·3 per cent. of the total number of workers in the firms where those schemes were in force. The average bonus or share in profits represented an addition to the wages of participants of 5·5 per cent. There was a great diversity in the schemes as regarded the form of bonus to workers. In about three-fifths of the schemes the bonus was paid in cash; in others it was paid to a provident fund, or it was partly paid in cash and the remainder paid to a provident fund. A more common type of scheme, however, was that in which the whole or part of the bonus was retained for investment in the capital of the undertaking, the other part (where all was not invested) being paid out in cash or retained on deposit with the employers for provident purposes. Many industrial undertakings were not capable of absorbing annual additions to capital, and success was in some cases only attained by keeping the capital account as low as possible. In more than half of the abandoned schemes the cause was traceable to a falling off in business and to the fact that there were no profits to share. The success or failure of profit-sharing doubtless depended largely on the type of scheme introduced, on its applicability to the particular business of the employer, and on the spirit in which it was worked by the two parties to the agreement. A section of the report deals briefly with profit-sharing and labour co-partnership in co-operative societies.

THE CORROSION OF BOILERS AND OF PIPING ON SHIPBOARD.*

BY LIEUTENANT COMMANDER FRANK LYON, U.S. NAVY.

THE writer's attention was drawn to this subject by experience in the U.S.S. "Oregon" and U.S.S. "New Jersey," experience which convinced him that the prescribed methods of preventing corrosion were neither certain nor adequate. From July, 1896, to August, 1899, as an assistant engineer, he served in the "Oregon," and for the greater part of this time was in direct charge of her boilers. She had five tubular boilers. The feed water was kept hot in practically an open tank and was at all times kept so strongly alkaline as to render it unfit for ordinary purposes. In this vessel corrosion of boilers or of piping was almost unknown.

He served from May, 1906, to May, 1909, as the senior engineer officer of the U.S.S. "New Jersey." Troubles from corrosion began immediately and continued throughout the three years. In two months from the time the ship was commissioned the copper suction and discharge piping to the circulating pumps of the dynamo condenser and ice machine corroded through in places. As these pipes are in the dynamo rooms this rapid action was, as usual, attributed to electrolysis from stray currents. The electrical installation had many grounds especially in wet weather, as most of the porcelain fittings were porous. Within a year the main and auxiliary injection and discharge piping in the engine-rooms had corroded through in many places. This could not be attributed to the galvanic action of stray currents with the same apparent certainty as that in the dynamo rooms, especially as the electric installation had, in the meantime, been made reasonably tight. The main injection and discharge piping was removed, holes were filled, and the inside of pipes given a wash with soft solder. No more troubles were experienced with them.

Within one year and a half the flushing system around the pumps and distillers was renewed in many places; the ice machine and dynamo condenser suction and discharge pipes to circulating pumps had corroded through again. An examination of all of the corroded pipes showed the troubles almost invariably to take place in bends and at or near flanges, the places where the copper pipes had been worked most. The corrosion was most noticeable in the piping in which the water is heated more or less between its entrance to and exit from the system. As no troubles were ever experienced with the discharge from the air pumps (main, auxiliary, or dynamo), or in the fire-room piping, there was a grave doubt cast on the stray-current galvanic-action theory.

The "New Jersey" had Babcock & Wilcox boilers. The feed tanks were placed under the main condensers with filter tanks at the top of one end. The dynamos were of the enclosed crank-case type using splash feed, with cylinders just above the crank case, and parts of the valve and piston rods entered both the steam and oil spaces. Originally there was no grease extracter between the dynamo air-pump discharge and the filter tank. Most of the lubricating oil used in the dynamos found its way into the feed tanks and boilers. The water in the boilers was kept slightly alkaline or neutral, using soda for the first year and lime after that time, as it was found that lime floated the oil to the surface better than soda. Due to fear of priming in these small drum boilers, the water was never kept as alkaline as that in the "Oregon's" boilers. Subsequently grease extractors were installed and the dynamo cylinders were raised so that no part of the rods entered both the steam and oil spaces, and the oil thereafter was kept out of the boilers. Up to this time practically no corrosion had taken place in the boilers and no damage to them had been caused by the oil.

In December, 1907, the screws holding together the ends of the composition packing rings in the water ends of three main feed pumps broke within a period of four days. These sharp ends shaved up the composition liners of the pumps and pumped them into the feed system. Later some of these chips or shavings were found in the boilers. Boiler corrosion began, and as it was practically coincident with the pump troubles, it was attributed to the ground-up liners that had gotten into the boilers through the feed system and to sea water from leaks in the condensers which developed from time to time. Zincs, the supposed palliatives of all corrosion troubles, were added in greater numbers. The zincs corroded rapidly, and so did the boilers. Tubes pitted through, hand-hole gasket seats corroded, and cross and side boxes and uprights suffered. In one period of two weeks, twelve changes of boilers for renewing pitted tubes were made. Most of the corrosion had taken place in the form of pitting and it was attributed to galvanic action from particles of composition, ground into the sides of the steel tubes by the turbine cleaners. When replacing hand-holes a liberal use of graphite on the gaskets had always been allowed.

It was felt that every effort to prevent corrosion and to keep the boilers clean had been made, yet destructive local corrosion was going on and increasing in effect in spite of the zincs, non-acidity of the water, cleaning, and other efforts to stop it. The Navy regulations had been followed, experiments had been made, yet the writer had failed in every particular to stop corrosion on metals with their surfaces in contact with water. He was detached from that duty, and left it, knowing that there was something woefully wrong in the methods he had pursued and with the general methods of treating corrosion on shipboard.

With this excellent grounding in a knowledge of the effects of corrosion, the writer has been engaged for the past three years, at the naval engineering experiment station, in an experimental investigation of the problem of preventing corrosion. Naturally much of the work has followed lines suggested by other investigators. The purpose of this paper is to present some of the results of this investigation, and with them, to explain why in the "Oregon" corrosion was prevented, while in the "New Jersey" it was induced by the methods employed.

Investigations were taken up, using the ferroxyl mount of Cushman and Walter. In this method the metals under examination are covered with a clear neutral jelly while the jelly is hot. The jelly contains two indicators—(1) ferro cyanide of potassium which combines with the metal at the points where it is dissolving into solution (the electropositive spots), giving a colour reaction characteristic of the metal with which it combines; and (2) phenolphthalein, which combines with the hydroxyl (OH) where the current is entering the metal from the liquid (the electronegative spots), giving the characteristic reaction of phenolphthalein in alkaline solutions. The same effect can be produced in a metal immersed in water if the water is not shaken enough to diffuse the colours. The mount in jelly can be preserved almost indefinitely if the surface of the jelly is kept covered with alcohol. By means of these mounts it may be seen that:—

On a good piece of steel or iron the potentials at different points in the surface are continually changing, while on a piece containing slag and segregated impurities or areas over which the molecule stresses are different, the potentials are more or less permanent. On steel this mount gives a blue compound at points where corrosion is going on.

A piece of scale from an old zinc removed from a boiler is electronegative to boiler steel and will cause it to corrode.

A new zinc-steel couple in the water mount shows the zinc adequately to protect the steel for about four days, then gradually to lose its effect until at from the fourteenth to the sixteenth day the protective action is entirely lost. The zinc then corrodes locally, while the steel corrodes over its entire surface.

Zinc scale from old zincs was seen to be electronegative to three grades of boiler steel, three grades of nearly pure irons, to four grades of cast iron; and to Admiralty condenser tubes, Muntz metal, tobin, phosphor, and manganese bronzes, and to naval composition. It was electropositive to monel metal, sheet copper, and to elephant bronzes.

Zincs that had just been cleaned and polished were at first entirely electropositive to steel boiler plate; after five days' immersion they were electropositive in some spots and negative in others to steel, electronegative to greater areas of the steel after ten days, and to the entire surface of the steel after twenty days.

Steel boiler tubes that had been properly expanded into the tube sheet, that is, evenly over the entire thickness of the tube sheet, were shown to be in about the same condition as that of the unexpanded tube. With tubes in which the

* From the "Journal of the American Society of Naval Engineers."

metal was stretched in expanding, due to improper placing of the expander rolls, pronounced permanent electropositive spots were produced throughout the thickness of the tube at the places where the metal was deformed over the edges of the tube or header sheet and also when the surface of the tube was cut by the expander rolls.

Specimens that had been broken in the testing machine showed themselves to be strongly electropositive in the breaks, and where the grips had squeezed or cut the metal, as compared with parts where the skin had not been broken.

In a machine steel rod that had been broken in a torsion machine the neutral axis could be followed for some distance from the break by its being electronegative to the outer or badly-twisted sections.

Some grades of irons and steels were seen to be electropositive to others and these results were confirmed by measurements on the potentiometer.

Graphite placed on steel surfaces showed it to be electronegative to the steel.

The difference of potential and current flowing was roughly measured on a potentiometer between a blue and a red area on the same plate of steel. The method indicated that the points were of different potential, but did not indicate the relative amounts of such differences or any means of accurately measuring them.

Acid Corrosion Test.—The relative corrosions of irons and steels were tried in distilled water and in acid solutions as follows: American ingot iron, wrought iron, steel boiler plate, and cast-iron specimens were corroded in distilled water and a rate of loss per unit of area per unit of time established for each. They were then removed and placed in the same concentration of sulphuric acid in exactly the same way and the rates similarly established. When these rates were compared there was no relation whatever between them. Some specimens that had corroded at about the same rates in distilled water corroded quite differently in the acid solution. As this was not the test wanted it was discarded. The acid corrosion test may be of value for certain specific uses but it certainly cannot be generalised from as an accelerated test.

Corrosion of Iron, Steel, and Some Non-ferrous Metals in Distilled and in Sea Waters.—These tests were made in glass jars, some sealed for a year, then left open until water was all evaporated and the pieces were dry, and others were left open and loss from evaporation made up from time to time by addition of water from the same source. The units are losses in milligrams per square inch of area in times as designated

Polished boiler-plate steel in distilled water, jars open:—

First 30 days	12·1	First year	186·0
Fifth 30 days	17·0	Second year	158·5

The products of corrosion were left in the jars and losses from evaporation were made up when surface of water was 1in. above the upper surface of the steel. This indicates that the presence of the products of corrosion does not accelerate corrosion, but rather that corrosion is retarded thereby.

Steel from the same plate and under the same conditions as the foregoing, with mill scale on top and bottom, the sides and ends being planed:—

First 30 days	12·1	First year	207·0
11th and 12th 30 days	19·9	Second year	182·4

At the end of the second year the mill scale had almost all been changed to ordinary rust and the appearances of pieces in this and the preceding tests were very much the same. The rates of loss for the last three periods of the second year were very nearly the same, 11·0 and 12·9 respectively. The pieces were turned over after each weighing, as the bottoms of the pieces next the glass did not lose their polish or mill scale, and the attack was principally on the top, sides, and ends. On a polished piece, with the same area always kept on the bottom, most of the polish remains after two years. This may be due to the light being kept away from the bottom of the specimen, or to the fact that the products of corrosion cannot diffuse away and be oxidised, and, therefore, that the potential of the solution is raised to that of the steel with which it is in contact before sufficient metal has been dissolved away to become noticeable. The latter is the writer's belief.

Polished steel, same conditions as the foregoing, except placed under and in contact with a sheet of copper of similar dimensions:—

First 30 days	17·9	First year	194·4
Third 30 days	18·7	Second year	192·0
11th and 12th 30 days	14·7		

The tops in contact with copper and the bottoms in contact with glass have much of the polish remaining, most of the attack having taken place on sides and ends.

Steel with mill scale on tops and bottoms, with sides and ends planed, placed under copper:—

First 30 days	26·0	First year	218·2
11th and 12th 30 days	14·8	Second year	180·0

Nearly all of the mill scale remained on tops and bottoms.

With the same steel under sheet brass, instead of under copper, very similar results were obtained.

Steel with mill scale under Muntz metal:—

First 30 days	28·4	First year	283·6
Second 30 days	29·5	Second year	236·4
11th and 12th 30 days	21·7		

Same as the foregoing except under Tobin bronze:—

First 30 days	21·5	First year	238·0
Second 30 days	26·0	Second year	222·0
11th and 12th 30 days	17·5		

Similar specimens under rolled Monel metal, with rolling finish on tops, bottoms, and ends of Monel:—

First 30 days	16·9	First year	233·4
8th and 5th 30 days	23·8	Second year	235·2
11th and 12th 30 days	19·2		

From an analysis of the above conditions it will be seen that corrosion has decreased with time in nearly every case on steel immersed in its own corrosion products; that the surfaces of steel in contact with some other surface does not corrode in the same way as on surfaces exposed to water alone, even when the metal in contact with it is much lower in potential than itself; that the surfaces exposed to water alone are more severely attacked when the specimen is in contact with a metal of lower potential; and that the attack depends upon the perfection of contact with the metal of lower potential. This was indicated in the tests with rolled Monel, Muntz metal, and Tobin bronze, which specimens were much thicker and, accordingly, heavier than the copper and brass plates; the pressure was greater and, therefore, the contact was better.

The following steels and irons in distilled water alone corroded in milligrams per square inch per thirty days' intervals as given. All pieces were planed all over, jars were sealed for first year, then left open until pieces were dry.

	First year.	Subsequently, while evaporating to dryness, jars open.
Class A steel boiler plate	15·3	21·9
B steel boiler plate	14·1	22·9
C steel boiler plate	13·7	21·9
American ingot iron	13·8	26·4
Cast iron, Navy specifications	16·2	27·5
ammonia fittings	17·6	26·8
machinery castings	15·9	27·5
grate bars	16·1	28·4

This is given to show the effect of increased air or oxygen. With the jars sealed there is not enough oxygen passed into the water to oxidise the dissolved products as fast as they can go into solution. The potential of the water is raised by the dissolved and unoxidised particles of iron in it. The difference of potential between the metal and the metal water solution is decreased and the rate of corrosion is decreased. With the jars open, oxygen is admitted, and the rate of corrosion is increased. An increase in the area of the water in contact with air up to a certain limit will increase the rate of corrosion of the metal.

The irons and steels that have shown themselves to be permanently of higher potentials than other irons and steels by the potentiometer measurements, ferroxyl mount, and by an alkaline concentration test, to be explained later, always have their rates of corrosion increased and that of the metal of lower potential decreased when they are con-

nected by a metallic contact in distilled, brackish, or sea water. This does not mean that the metal of lower potential does not corrode, but that its rate of corrosion is decreased. Parasitic corrosion is going on over its surface at the same time that it is acting to increase the rate of corrosion on the piece of higher potential.

In no case has a piece of iron or steel, connected by metallic contact to new zinc of the same size, corroded less in a period of thirty days than a piece of the same steel placed near it in the same water and not connected by metallic contact to the zinc.

When three grades of nearly pure irons, four grades of cast irons, and two grades of boiler steel were all connected to one grade of class B steel boiler plate, only two grades of cast irons reduced the rate on the steel below that obtained when pieces of the same steel were connected in pairs.

With the nickel bronzes the rate of corrosion on steel connected by metallic conductors to them was generally less than that on the same steel connected to the zinc-copper and tin-copper alloys. Also, similarly, the greater the percentage of nickel in the alloy, the less the rate of corrosion on steel similarly connected thereto. Pure nickel is less corrosive to steel than is nearly pure copper under the same circumstances.

Taking the rate of corrosion of boiler-plate steel in sea water when jars were closed as 100, the same rate with jars open was 122·6. The rates in wrought iron and nearly pure iron under similar circumstances were 73·4 to 107·7 and 87·7 to 137·5 respectively. With the same three metals placed under and in contact with manganese bronze the rates were 112·3 to 135·9, 111·8 to 139·0, and 108·2 to 140·5 respectively. With the same steel under manganese and phosphor bronzes and composition G, the rates were 112·3 to 135·9, 109·2 to 127·7, and 109·2 to 131·3 respectively. These differences are no greater than will be found between specimens of the same plate immersed alone in distilled water. In analysing the foregoing it is seen that wrought iron and nearly pure iron are acted upon very differently from steel by a reduction of the oxygen supply, that under the same manganese bronze they are corroded to nearly the same amount, and with the one steel similarly placed under different bronzes its rate of corrosion is very nearly the same It is well to note here that the two metals must be in metallic contact, otherwise each metal will corrode as if alone in the water even when they are very close together. The effect one metal will have upon another depends more upon the perfection of the contact than upon any other one thing. Copper in surface contact with steel in distilled water increases the corrosion of steel from 8 to 12 per cent., while with the two metals screwed on to the ends of an iron wire, the rate is increased from 79 to 80 per cent.

With non-ferrous metals and cast irons alone in sea water the rates of the losses with jars sealed and open, respectively, in milligrams per square inch, for 30-day periods, were as follows:—

	Jars sealed, 12 periods.	Jars open. 3 periods.
Copper	1·5	3·0
Victor silver	plus 1·5	minus 3·6
Phosphor bronze	9·9	15·1
Composition G	3·8	4·8
Muntz metal	1·3	4·0
Manganese bronze	1·7	2·2
Rolled Monel bar	1·7	1·0
Cast iron, naval specifications	20·9	25·0
ammonia fittings	18·4	22·7
machinery castings	21·3	25·9
grate bars	20·7	22·1

Note the great rate of corrosion on the phosphor bronze in comparison with the others. It is almost half as corrodible as cast iron with jars sealed, and more than half with them open. With boiler-plate steel in distilled and in sea waters containing graphite, pieces covered with graphite lost from 3 to 4 times as much per square inch of area exposed as did similar pieces placed in the same water without graphite. The increased rate of corrosion depended to quite a large extent upon the percentage of area covered and also upon the purity of the graphite. With pieces of steel immersed in water condensed from exhaust steam from an engine using different kinds of cylinder lubricants (the engine using both saturated and 600° Fah. superheated steam at 300lbs. gauge pressure), there was practically no difference during a 20 months' test in the rate of corrosion as compared with that obtained in steam condensed under similar conditions except free from oil.

The Cause of the Corrosion of the "New Jersey's" Boilers.—While carrying out these tests it occurred to the writer to calculate the approximate concentration of lime that had been kept in the "New Jersey's" boilers. This was found to have been at about the critical concentration for boiler steel, so that in trying to stop corrosion by the use of lime, zincs, and other methods, local corrosion or pitting had been induced. Had twice as much lime been used, no local corrosion would have occurred even with the composition liners and air. To prove this, the small steel boiler, with copper tubes, was run for fifteen days at a saturation of 2,000 grains of chlorine per gallon, keeping the water at a concentration of 3 per cent. normal with soda. Steam pressure carried was 180lbs. gauge. At the end of that time five test pieces placed as follows showed no signs of corrosion, and no loss of weight: One at bottom of shell at smoke-pipe end; one at bottom of furnace end; one on top of crown sheet; one laid across copper tubes at middle of their height; and one laid across copper tubes near the water level. The boiler was fed with brackish water from the Severn river, and was given a blow-down when the chlorine content was found above 2,200.

It thus was demonstrated why the boilers of the "Oregon" showed no signs of corrosion in three years, and why those of the "New Jersey" were considerably corroded in the same time. In the one case corrosion had been prevented by keeping the water strongly alkaline, in the other it had been materially aided by an insufficient degree of alkalinity.

In calculating the percentage of soda concentration kept in the boilers of the "New Jersey" it was seen that it was slightly lower than was critical, but still a dangerous one to use. The reason why there was no corrosion before the dynamos of the "New Jersey" were raised was that there was always a film of oil between the metal and the water, so no bad effects from corrosion could occur. Oil on the surface of water passes oxygen to it, and thereby aids the corrosion by removing the dissolved particles of iron from solution, but oil on the surface of the metal prevents water from getting to it, and thereby prevents corrosion, so long as the skin of oil is intact. As soon as the access of oil to the boilers was prevented, the tubes began to pit and corrosion began. It was only partly due to any particles of composition, partly to the graphite from the gaskets, but principally to the water conditions and to zinc scale. Had the water been kept properly alkaline the other three conditions would have had no effect.

The writer has no hesitancy in saying that any boiler using any water can be kept from corroding for any length of time, if treated with soda, and if its concentration is maintained at or above 3 per cent. normal alkaline strength. If the water is not to be kept sufficiently alkaline, it had better be kept neutral.

Summary.—From practical experience, study, and much experimental work, the writer's conception of corrosion is as follows:—

1. All metals dissolve in water or in water solutions if the electric potential of the metal at any point is higher than that of the water or solution.

2. Corrosion products or rust result from the oxidation of the dissolved particles of metal held in solution.

3. The solution pressure of a metal in any liquid is the increase in electrical potential of the metal over that of the liquid.

4. If the potential of the metal in contact with water is higher all over its surface than that of the water it will corrode evenly or nearly so. If the potential of only one point in the surface of the metal is higher than that of the water it will pit or corrode locally at that spot. Metals do not pit or groove noticeably in distilled water, acid solutions, or when in contact with a metal of lower electrical potential in water.

5. Local corrosion on bare iron or steel only takes place in water the potential of which has been raised until it is higher than that of certain areas of the metal,

6. Oxygen and carbonic acid do not cause corrosion. If the metal can dissolve they do increase its rate by removing the particles of it from the liquid, and thereby preventing an increase in the potential of the liquid.

7. When iron is placed in perfectly pure water into which no oxygen can dissolve, the iron first tends to dissolve, due to its higher potential. Each particle of iron dissolved raises the potential of the water and exposes a new particle of iron. Eventually the potential of the water will be equal to that of the metal at every point, dissolving will stop, and the solution will be saturated. Now if oxygen is present in the water, as the iron is dissolved it will be oxidised, the potential of the liquid will be raised only to the point where there is equilibrium between the rate of solution of the iron and that of the oxygen, and corrosion of the iron will continue.

8. Metals corrode in sea water at a greater rate than in distilled water, due to the higher conductivity of the former. The metal particles get away from the metal and in contact with oxygen or CO_2 more freely and the potential of the water is kept from rising. The natural potential of sea water is not raised to any appreciable extent by the metallic salts it contains, because the high potential metals of those salts are mostly combined with strong acid radicals such as chlorides and sulphates.

9. Hydrogen and all elements lower in the electromotive series than hydrogen decrease the potential of water in which they are in solution. All elements electropositive to hydrogen increase the potential of the water when they are in solution.

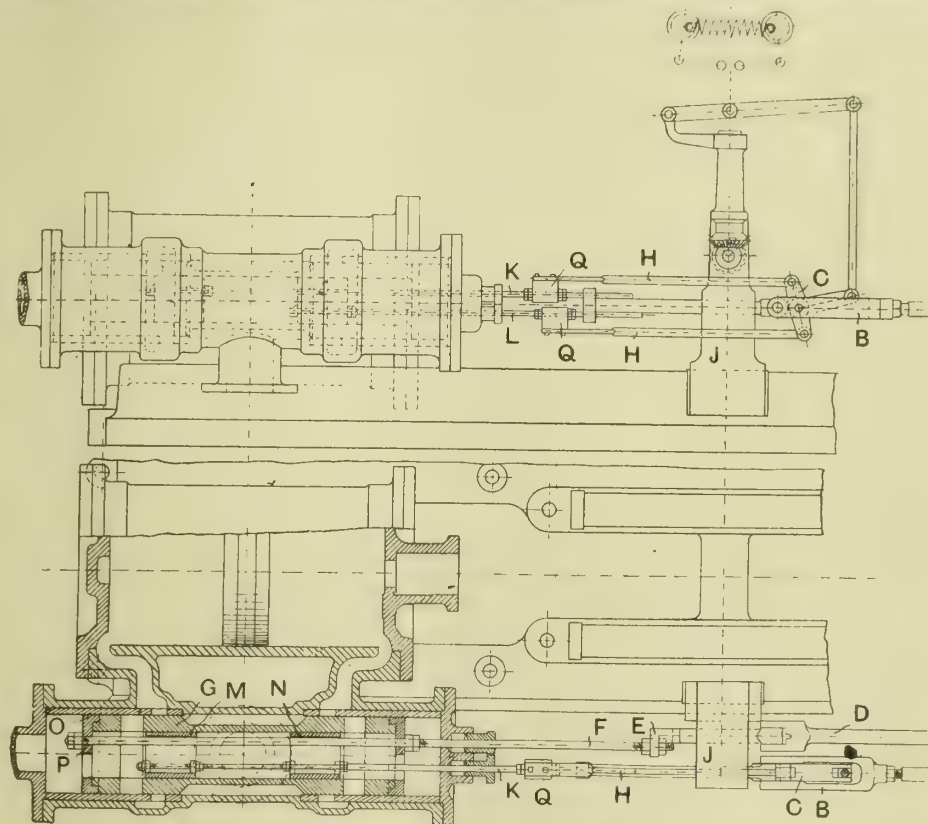
10. The alkalies are the highest in the electromotive series, and are, therefore, the most soluble in water. They raise the potential of water in which they are in solution.

11. The sodium salts of weak acids increase the potential of water at a greater rate than do the same salts of strong acids.

12. The potential of a solution containing a metal higher in the electromotive series than another metal immersed in it will increase faster with a rise in temperature than that of the immersed metal.

CUT-OFF VALVES FOR STEAM ENGINES.

An arrangement for varying the cut-off of the steam in the cylinders of steam engines when working expansively, the invention of Messrs. R. & W. Lees, Park Foundry, Hollinwood, near Oldham, is shown in the accompanying illustration. The main valve G is of the hollow piston type and the cut-off valves M N are also hollow pistons working within the main valve G. The main valve has separate end pieces O with projecting lugs P, by means of which the valve is secured to the main valve spindle F. The valve spindle is connected to the slide E working in the valve spindle bracket J and receiving its motion from the main eccentric rod D. The cut-off valves M N have an axial motion relative to the main valve G. The cut-off valves are worked by separate valve spindles K L, the spindle K of the valve M passing through the interior of the valve N. The spindles K L are attached to the valve rod blocks Q, these blocks being connected to the double arm of a T-shaped lever C by means of rods H. These rods are connected to lever C by means of pin joints and are flattened at the opposite ends to form a flexible connection with the valve rod blocks Q. The T-shaped lever C is suspended between the arms of the forked-end eccentric rod B, the single arm of the lever being connected to the governing mechanism by means of a vertical link. The variation in the point of cut-off is effected by varying the distance apart of the cut-off valves M and N, the further apart the valves are situated, the earlier the cut-off takes place. This variation is effected by the governing mechanism altering the position of the T-shaped lever C. An increase in the speed of the engine causes the lever C to be rotated in a counter-clockwise direction and the valves M and N to be moved further away from each other, thus causing an earlier cut-off of the steam and a decrease in the speed of the engine. If the speed of the engine be decreased, the lever C moves in a clockwise direction, the valves M and N are brought nearer together, causing a later cut-off and an increase in the speed of the engine.



Cut-off Valves for Steam Engines.

A COLUMN TESTING MACHINE.

A paper describing a column testing machine was recently read by Prof. E. G. Coker, before the Physical Society. The conditions of fixture of the ends of columns, and the large influence this had upon their strength, generally made it necessary to use special testing machines for these members, in which the end plates applying the load were accurately parallel, and remained so during a test. If only rough measurements of the load were required this offered no serious difficulty, but accurate measurement involved elaborate mechanical devices, some of which were briefly referred to in the paper. This difficulty was, he said, overcome in a simple manner by supporting one pressure plate by two or more annular diaphragms spaced at considerable intervals, and clamped at their outer edges to a fixed casing in such a manner that only one degree of freedom was possible. This construction was carried out in the machine described in the paper. The total load on the pressure plate supported in this way could be measured by a loaded lever system, or other suitable means. The other pressure plate might be carried on guides, and the load applied by screws, hydraulic pressure, or other suitable means. Rectangular plates or wires might also be used in place of annular diaphragms, and a model showing an application to a compression machine was described. Photographs of celluloid columns were shown under stress, and the colours produced by temporary double refraction indicated that the loads were satisfactorily applied in a machine of this type.

Millwall Dock Boiler Explosion.—The formal investigation ordered by the Board of Trade to be held in regard to the boiler explosion at Millwall Dock is fixed for hearing in the Council Chamber, Council Offices, High Street, Poplar, E., on Tuesday, the 17th inst., at 11 a.m.

WASTE HEAT UTILISATION.

THE subject of "Waste Heat Utilisation" was dealt with in a paper by Mr. I. V. Robinson, M.I.Mech.E., read before the Cleveland Institution of Engineers on December 2nd. Waste heat was, he said, now being used in many forms, *i.e.*: (1) Exhaust steam: (a) steady supply from non-condensing blowing engines, &c.; (b) intermittent supply from winding engines. (2) Waste gases: (a) blastfurnace gas; (b) coke-oven gas.

The utilisation of low-pressure steam in a turbine was first carried out by Sir C. A. Parsons in 1893, but no great development of this idea occurred till Prof. Rateau introduced means for the economical utilisation of an intermittent supply of steam. The steady supply of steam was usually obtained from the exhaust of blowing, pumping, and air-compresser engines. Incidentally the author mentioned that the chief example of low-pressure turbines using a steady supply of steam was provided by large liners having high-pressure reciprocating engines and low-pressure turbines. Before deciding to install a low-pressure turbine, the condition and probable economical life of the engines should be considered, as undoubtedly, in many cases, low-pressure turbines had been installed in connection with engines which cost too much for maintenance, and the end of whose economical life was rapidly approaching. It might then be desired to install other type of plant, such as a turbo-blower, but the use of a reciprocating engine was obligatory owing to the existence of a low-pressure turbine. It would always be better to install a medium-pressure turbine so that a reasonable efficiency could be obtained should it be decided to install other types of prime movers when the existing ones were scrapped. A pure low-pressure was rarely justified.

The economy and price were, he observed, intimately connected in a turbine, particularly in a medium-pressure impulse turbine. By increasing the number of stages the cost was increased, and the economy improved and vice versâ. In cases where there was an ample amount of steam for the power required, a cheap turbine would be satisfactory. In a power company's waste-heat station, where a purchaser could be found for all power that was generated, a more expensive turbine would be justified on account of its improved economy and correspondingly greater output from the available exhaust steam. A point to be considered was the maintenance of economy over a long period. The steam consumption of some turbines increased rapidly with time, owing to the use of too high steam and blade velocities.

With medium-pressure turbines the condensing plant was, he said, most important, as the improvement due to a higher vacuum was greater with medium-pressure than with high-pressure turbines. The condensing plant deserved very special consideration in order to obtain the maximum vacuum. It might be of either the surface or jet type, the former always with bad and the latter only with good circulating water. The surface condenser was generally to be preferred, but it was the more expensive of the two. Jet condensers were now made that would give vacua as high as was required, but their drawback was that they were likely to lose the vacua if a sudden rush of steam or air entered the condenser. This caused the water to rise in the condenser, and although this was guarded against by vacuum breakers operated by the rise of water level, the water might rise into the turbine and damage the blades. Jet condensers were divided into two main classes, those with and those without air pumps, the latter being termed "ejector condensers." These were only to be recommended for a turbine which would generally be working at full load, as at low loads the vacuum was unstable, and the power consumption was higher than with jet or surface condensers.

In the majority of installations now, rotary air pumps were, he said, being adopted. There were three well-known pumps on the market, the Leblanc, the Kinetic, and the Rees-Roturbo. They were brought out in the order given. The Leblanc pump was made in units up to 5,000 kw. each. The Kinetic had been adopted for the largest turbines built in this country, namely, the 25,000 kw. set by Messrs. C. A. Parsons and Co., for Chicago, and the 15,000 kw. set by Messrs. James Howden & Co., for Manchester. The Rees-Roturbo air pump had up to now only been used in plants up to about 1,500 kw. each. Rotary air pumps were reliable, and more suitable for obtaining the highest vacua than reciprocating air pumps. Up to the present time, the power absorbed by them was greater than that required by a reciprocating pump for equal power, but there were signs that this difference would be reduced and probably eliminated. Rotary air pumps might be compared by noting the vacuum that each would maintain when exhausting a vessel into which air was admitted through a nozzle of known dimensions. With equal power absorbed it would probably be found that one pump was capable of dealing with the air admitted through a larger nozzle, thus having a larger margin to deal with abnormal air leakages.

For mixed-pressure turbines some means of equalising the supply of intermittent low-pressure steam were necessary. In some cases where economy was not essential, old boiler shells were used as receivers, but in the majority of cases an accumulator was required. The essential requirements in an accumulator were: (1) Capacity to absorb steam at a high rate, possibly four or five times the evaporative rate. (2) Small drop of pressure through the apparatus. (3) Economy in steam. Under normal conditions and with a properly designed accumulator the safety valve should not lift unless the steam available was in excess of the steam required to carry the load. It was often difficult to get beforehand accurate data regarding the peak rate of flow. The accumulator should be designed so as to bring all the water into rapid circulation, thus ensuring a high absorption rate.

In the case of winding engines, where the exhaust contained oil, oil separators had to be provided, but in addition to these there was in the Rateau-Morison accumulator an oil-scumming device which caused all the surface float oil to be collected at one end of the accumulator. This object was achieved by allowing the steam escaping from the nozzle under water level to emerge in one direction only, thus causing a decided water surface motion carrying the oily scum with it. It was concentrated and discharged to atmosphere by a scumming cock.

THERMOMAGNETIC STUDY OF STEEL.

IN a paper on this subject recently read before the Physical Society of London, Dr. S. W. J. Smith said that thermomagnetic measurements made it increasingly evident that the magnetic properties of steels were frequently those of mixtures of magnetic substances, each possessing characteristic properties, which contributed in a comparatively definite way to the properties of the material as a whole. In the case of a simple ferromagnetic substance, magnetising fields could generally be found in which the permeability variation with temperature was comparatively small except in the neighbourhood of the critical temperature. In such fields there was a very clearly marked peak in the permeability temperature curve for the substance. The explanation of this peak, which the molecular theory afforded, was well known, and suggested that the phenomenon should be found common to all ferromagnetic substances. The immediate object of the present paper was to show that it was exhibited by the carbide of iron (cementite), which existed in annealed carbon steels. For this purpose it was not necessary to isolate the carbide because the phenomenon was quite clearly discernible in the permeability temperature curves for the steel. The particular steel examined contained 0·85 per cent. of carbon. It was found that the fields necessary to evoke the comparatively sudden variations in the permeability of the carbide above described were small, and such that the permeability variation of the iron present along with the carbide was slight in the neighbourhood of the critical temperature of the latter. The sudden gain and loss of permeability by the carbide as the temperature altered would be roughly equivalent to sudden removal and replacement of gaps in the magnetic circuit through the steel. They should therefore be attended by correspondingly sudden rise and fall of the apparent permeability of the material as a whole. This was found to be the case. There was a sharply-marked peak near 210° C. upon the permeability temperature curve for the steel. In the absence of measurements between 200° C. and 220° C. the peak would escape notice, and it was for this reason, probably, that it had not been recorded before. It could scarcely be found by accident.

HAULAGE CLIPS.*

BY W. G. SALT AND A. L. LOVATT.

THE advent of the mechanical clip for use in mines was simultaneous with the introduction of the endless-rope system of haulage, and since its adoption innumerable forms and types of clips for attaching and detaching the pit tubs to and from the haulage ropes have been brought before the notice of colliery officials. A small percentage of the early designs survived the severe tests to which they were subjected, and are now in use to some considerable extent in modified form, but the remainder failed hopelessly to comply with the requirements even of the most reasonable and least difficult forms of endless haulage, and became obsolete almost immediately after their introduction. However, one by one the difficulties have been dealt with until now there are a number of clips that can be said to be satisfactory, but to the writers' knowledge there is no single clip on the market at the present day that will successfully negotiate all the conditions that are often to be found at a mine. The object of the paper is to specify as far as possible the types and makes of clips suited to the various conditions of haulage to be found in the North Staffordshire district. The essential qualities of a good clip are:—

(1) A clip must be made sufficiently strong, with a margin of safety, to do the work that is required and to withstand rough usage. If, however, the design of the clip is over liberal, the desired results would not be obtained, for if the tub or tubs became derailed, serious damage might be caused to the rope or hauling machinery if the clip did not act in the nature of a safety valve.

(2) Its design and construction should be such as to allow of its gaining and retaining a firm grip on the rope the moment it is attached.

(3) The jaws of the clip should have a good bearing on the rope of at least 70 per cent. of the circumference of the rope, and should embrace all the strands of the rope with a minimum length of clip jaw.

(4) A good margin for wear should be arranged, and easy adjustment by the person using the clip should also be allowed for.

(5) The design and construction should be as simple as possible; the fewer parts the better, and such as to allow of its being easily attached and detached from the rope, the detachment being clean and certain.

(6) The gripping surfaces should be so arranged as not to kink the rope when under working conditions. If the kinking effect is reduced to a minimum, the wear on the rope will also be reduced, and consequently the life increased.

(7) A clip should be capable of being automatically detached from the rope, and ideally should be of such a design as to work satisfactorily under any one or all of the conditions prevailing at a mine.

The following controlling factors must be taken into account in the adoption of a clip:—

(1) **Inclination.** — When the inclination of a road is great, a strong clip with attachments made of the best materials should be adopted, preferably of the lever type, so as to adapt itself to the varying diameters of the rope. The clips suitable for these conditions are as follows: Sylvester & Weaver and Stubbs, &c., for under-rope, and Aspinall for over-rope; but when the inclination is less, other clips may be used with good results, such as the Smallman, and Craven & Bradley.

(2) **Undulating or Varying Gradients.**—When the road is dipping first in one direction and then in another, the clip is then required to act in a pulling position or in a holding-back position. Only a few clips are used with a certain amount of success under these conditions—such as the Stubbs, Smallman, and Craven & Bradley.

(3) **Level Roads.**—Various types of clip are in use under such conditions, which is the easiest method of applying haulage clips. Those which may be used under these conditions are the Stubbs, Smallman, "Drop-down" clip, Elswick, and Craven & Bradley, &c.

(4) **Direction of Road (when the road is not straight).**—Under these conditions a number of clips are successfully used to advantage, but are not absolutely infallible, as there is a tendency when a clip is attached to a rope and is coming round a bend for the rope to slip out of the groove of a pulley. Should this happen there would be damage caused both to the clip and the rope. Under these conditions there is a large amount of wear on the clip and rope. A number of clips may be used under these conditions, such as the Stubbs, Smallman, and the Craven & Bradley.

(5) **Under and Over Rope.**—To the writers' knowledge, no clip is suitable for the two conditions unless certain alterations are made, and even then these alterations can only be accomplished in the case of a few clips. For the over-rope haulage, lashing chains are used, but latterly have been superseded by the Swan clip or preferably the Aspinall clip.

Clips may be divided into three classes, namely, the lever type, screw type, and wedge type. Examples of the lever type are as follows: Stubbs, Sylvester & Weaver, Smallman, Bull-dog, and Aspinall. Examples of the wedge type are the Stubbs and the Smallman. Examples of the screw type are the Craven & Bradley and the Elswick. There are many other types of clips owing to the fact that most collieries have designs of their own, and each particular type is assumed to be the best for the system of haulage in use. Examples: "Drop-down" clip and Swan clip.

The lashing chain is extensively used at some collieries, and although not a clip, it is used for the same purpose. The chain is about 10ft. long, having a hook at one end which is attached to the draw-bar of the tub. The other end is coiled a few times round the rope and hooked into the chain near the rope. When the road is undulating, it is necessary to use two chains, one attached to the front end for pulling, and the other attached to the back end for holding back.

The lever type of clip is mostly adapted for inclines, as it adjusts itself to the varying diameter of the rope caused by the weight on the rope. It is a well-known fact that there is a difference in the diameter of a rope, working on an incline plane, between the top and bottom. The writers have carried out experiments on a rope $1\frac{1}{4}$in. diam., which had worn down to $1\frac{3}{16}$in. Taking several parts of the rope, they found a difference of $\frac{1}{16}$in. diam. on the same point of the rope between the top and bottom of an incline 800 yards long, varying from 13° to 20°. These tests were made when there was less than half the working load on the rope. The authors have no doubt this variation would be more noticeable with the rope working on full load, and especially so in the case of a new rope, when the hempen core is large and the strands not properly bedded in their places.

The screw type of clip does not adjust itself to the varying diameter of the rope, so that it is not suitable for heavy haulage on a steep gradient. The writers know of a case where a youth was stationed at a point in a dip to tighten the grip of the clip on the haulage rope.

As to the advantages of the various types, the Bull-dog, which is of the lever type, has given a certain amount of satisfaction, but its disadvantages far outweigh its advantages. It can be adopted when the load is against the gradient, as it is dependent on the load for its grip on the rope, and it adjusts itself to the varying diameter of the rope.

As to the Sylvester & Weaver, which is of the cam and lever type, its advantages over those of the Bull-dog type are that it has a guard to prevent the cam from splitting or opening the rope; also that it is a very strong clip, and will work on a steep incline with safety, and will adjust itself to the varying diameter of the rope. At collieries in the district the clip is working satisfactorily. At Norton Colliery this clip draws two loads up an incline of 1 in 3, each weighing 15 cwts. At one time the pivot was a weak point in the clips and occasionally broke. Experiments were made with several qualities of steel pivots subjected to a dead shearing strain with the following results:—

	Tons.	Cwts.
Bessemer steel pivot	14	10
Mild ,, ,, (case-hardened)	17	7
Silver ,, ,, (not hardened)	21	12
Nickel ,, ,, (not hardened)	22	10

The connecting rod was also tested at the same time, the hook of which straightened out with a dead load of one ton.

The Stubbs clip is constructed on the new wedge principle,

* Abstract of paper read before the North Staffordshire Institute of Mining and Mechanical Engineers.

introducing the wedge frame. It is automatically detachable and attachable, and does not kink the rope when working in a forward position. It adjusts itself to the varying diameter of the rope, and will work on either steep gradients, undulating or level roads. The Smallman clip has been used with success, not only on level roads, but on undulating roads and round bends in the road. The Craven & Bradley (a screw clip) is giving satisfaction in the district, and each clip is capable of drawing up an incline of 1 in 3 a run of three tubs, weighing two tons, at a speed of two miles per hour. Its advantages are that it can be used on level and undulating roads. The Elswick is also a screw clip. The jaws of this clip, by which the rope is gripped, act almost like a clamp. It may be used on undulating roads. The clip known among miners by the name of "Collar" clip, very much resembles a pair of blacksmith's tongs. It is cheaply produced and very easily repaired. The Light Haulage clip belongs to the lever wedge type; it is very useful and simple. Its advantages are that it is cheap and light, and is adapted to undulating and level roads. It is automatically detachable. The Aspinall clip is used for over-rope haulage. At a local colliery this clip is drawing one tub weighing 10 cwts. up an incline of 30°. It adjusts itself to the varying diameter of the rope. The heavier the load, the better is the grip.

THE USE OF CHILLS TO OVERCOME LIQUID CONTRACTION.

A PAPER on "The use of Chills to Overcome Liquid Contraction," illustrated by lantern slides, was read by Mr. R. Carrick, of Shipley, at a meeting of the Lancashire branch of the British Foundrymen's Association on Saturday last. Of the many difficulties that every day beset the path of the foundryman, there was, he observed, probably none that was the source of so much trouble, or produced so many wasters, as liquid contraction. The term "liquid contraction" was of comparatively recent origin, and one that had been objected to in different quarters. The term more generally used and understood was "shrinkage," and yet this had so frequently been used as synonymous with contraction (especially by patternmakers and others outside the foundry) that it was very essential that some distinction be made; and, to the author's mind, the term "liquid contraction," or, perhaps, better still, "liquid shrinkage," admirably met the case. Longmuir and McWilliam state in their book, "liquid shrinking refers to the gradual lessening in volume of fluid metal as it approaches the solidification point," and although the cause of liquid and solid contraction was exactly the same, the effect was entirely different. It was well known that different brands of iron varied considerably in the amount of liquid contraction, and that it was quite possible by judicious mixing to reduce it to a minimum. But having done our utmost in this respect, and having consulted the chemist, metallurgist, and foundry expert, we still found ourselves with numerous problems of leakages, porosity, and spongy places due to liquid contraction.

The use of the feeding rod in the hands of a competent man might do a great deal towards getting a casting sound, but there were, he said, scores of cases where it was impossible to get absolute solidity, even with the feeding rod, and there were still more cases where it was impossible to get near the heavy section with a feeding rod at all, and consequently other methods must be adopted, or else the castings must be left in an unsound condition at that point.

The author next referred to some well-known cases, viz., hubs of spur wheels, blank wheels, flywheels, pulleys, &c. The majority of these were very similar in design, and were jobs that frequently gave trouble, owing to not being sound in the hub. Almost without exception these had a large fillet at the point where they connected with the arms or web, and it was at this point where porosity occurred. A chill cast in the centre instead of a core was likely to be much more effective than the feeding rod. Further, there was the time saved in feeding, not to mention the energy and vitality of the moulder. But it not infrequently happened that when the moulder had done his utmost with the feeding rod, and had fed it very thoroughly (in the case of fairly heavy hubs) there might still be porosity or sponginess. This might not be entirely due to liquid shrinkage, but was probably due to the carbon separating out in the form of graphite, owing to the slower rate of cooling at the thickest section of the casting. This was very clearly brought home to the author in the case of lathe face-plates, which prior to the use of chills had been a real source of trouble in the shop. The hole would appear to be fairly sound when it was bored, the plate would then be turned up, but when the thread came to be cut it would often crumb and fall away right in the centre of the hole at the root of the thread, the casting being consequently scrapped. A chill effectively cured this, and scores had since been made without a single failure; moreover, a much better wearing thread was obtained.

Steam-, gas-, and oil-engine cylinders, valves, engine beds, centrifugal pumps, tee pipes, lathe turrets, and many others, were castings that could be greatly improved by the use of chills. He emphasized that it was not advisable to use inferior iron for the castings mentioned. On the other hand it was of the utmost importance to use the very best iron suitable for the various classes of work referred to. But it was well to remember that even with the best mixtures, where a very slow rate of cooling was got, one was liable to get an open, porous, and weak body of metal at that point. If, however, a chill of the correct design and thickness could be got to the thick section, and solidification thereby accelerated, all danger of porosity or sponginess in that casting was likely to be eliminated. It should be clearly understood that although these were referred to as chills, the end in view was to avoid chilling in the ordinary sense of the word, and simply accelerate solidification, and thereby give the carbon less time to separate out in the form of free or graphitic carbon, but more in the combined form, and thereby give a closer, stronger, and more solid section than would otherwise be obtained. In reality the term "chill," as here used, and as it was being frequently used every day, was a misnomer, and unfortunately not only did it convey a wrong impression generally, but it created a feeling of suspicion in the mind of the employer and the foreman machinist. They naturally associated the term "chill" with extreme hardness, and were immediately on the look out for trouble; even if they did not always find it, they had a ready excuse for excess time in machining. As foundrymen they could hardly be blamed, for they were simply interpreting the word in its real sense. The remedy for this lay with ourselves; *i.e.*, change the term. Mr. F. J. Cook, of Birmingham, had suggested the use of the terms "Grey Chill" and "White Chill," but while this might meet the case with foundrymen, it would be hardly likely to get over the prejudice in the machine shop. The author suggested that this question be dealt with by the British Foundrymen's Association Council at their next meeting, and a committee be appointed to devise a suitable term that would convey to all associated with the foundry the correct idea.

In certain cases it was usual for the chill to be removed as soon as the casting had solidified. The writer had also expressly stated that the object of the chill was to cause the casting to solidify more rapidly than it would under ordinary conditions. When the casting had solidified the object of the chill was accomplished, and to leave it on was simply to make the casting harder than was necessary, and thereby cause increased cost in machining. If removed, however, and the casting allowed to cool under normal conditions there would be little fear of any complaints about extreme hardness. The author mentioned that he was using hundreds of chills every day, and seldom had a complaint concerning hardness.

Regarding the removal of the chills, it was not general practice to take all of them away immediately the casting had solidified, but only in cases where they were deemed likely to cause extreme hardness if left until the casting became cold. It would hardly be possible to enumerate the various cases where it was necessary to remove the chills; this was a matter for individual observation and experience, and judicious handling of the chills along these lines was very vital. The author did not wish the previous sentence to convey the idea that there were cases where it was necessary to leave the chill until the casting was cold; in all cases where the only object was to prevent segregation by causing quick solidification (and it was from this standpoint alone that the question was now being dealt with) it was advisable to remove the chill as soon as possible after solidification,

although this was not always done. The great trouble about cast iron was not so much the amount of metalloids as that with very slow cooling segregation took place and destroyed the homogeneity of the metal. It was not possible to prevent segregation altogether in the case of very heavy sections and get a perfectly homogeneous structure throughout, but it was possible to greatly improve large quantities of castings that were being turned out to-day, solely by studying the heat treatment of the cast iron after it had entered the mould. Incidentally, the author stated that he believed it was along these lines that the next great development in the foundry industry would move, *i.e.*, the use of iron or permanent moulds, the object of which would not only be to cheapen production, but to get greatly improved castings by preventing segregation.

He did not recommend the use of chills as the great panacea for all a foundryman's troubles, for all practical foundrymen knew that there were precautions that must be taken when using them. They must be free from moisture and rust, also of correct form and thickness, and care must be taken that the runner did not impinge on them when pouring, &c. They might, he said, easily become an addition to the foundryman's already numerous troubles, but it might again be emphasized that carefully employed they became a very effective factor in preventing liquid contraction, segregation, and frequently in helping to overcome difficulties that might arise in grading the iron, owing to the great variations in the thickness of numbers of small castings in one heat.

Referring finally to the coating of the chills, he did not think that there was any special virtue in any of the numerous coatings that were recommended. For chills that were entirely surrounded by metal ordinary clay-wash and composition blacking could be used, and in cases where only one face was exposed to the metal, a mixture of oil and plumbago. So far, these had answered the purpose better than any of the patent mixings often recommended. The success of the chill *did not depend* so much on the coating as on other things, *i.e.*, getting them at the right point and of the correct shape, and removing them at the proper time. These were the things that required the most consideration; coating was more a matter of detail and taste.

Manchester Association of Engineers.—On Friday evening, the 6th inst., over 200 members of the above association had the privilege of inspecting the extensive motor-car works of Messrs. The Belsize Motors, Ltd., Clayton, on arrival being received by the managing director, Mr. Jas. Hoyle Smith. At the present time the works cover an area of over 7 acres and are employing approximately over 1,500 men, all of whom are engaged in the production of touring and pleasure cars, together with taxis, fire engine, and commercial vehicles, a business which in this district is growing enormously from year to year. On the conclusion of the visit, the thanks of the members for the privilege afforded, in the absence of the President (Mr. Charles Day), were conveyed to Mr. Hoyle Smith by Mr. Wm. Fox (ex-president) and Mr. Joseph H. Stubbs (past-president).

Steam Friction in Turbine Wheels.—At a meeting of the Scientific Society of the Royal Technical College, Glasgow, held on Saturday last, Mr. William Kerr read a paper on "Steam Friction in Turbine Wheels." The lecturer divided steam friction into two classes, disc friction and vane friction, which was commonly called "ventilation friction," and described the experiments of Odell, Stodola, Lasche, and Lewicke, giving the results determined in their experiments. Mr. Kerr discussed the results of his own investigations on the college turbine plant as Beilby Research Scholar. After describing the plant in detail, the lecturer dealt fully with his methods of experimenting, and showed the results obtained in a series of three-ordinate graphs, showing the variation of friction effects with speed and steam density. The latter part of the lecture showed the relationship between the various experimenters' results. In the course of the discussion Prof. Mellanby referred to the generosity of a local gentleman who had presented sufficient money for the installation in the Royal Technical College of turbine plant of a sufficient size to enable research work to be carried on.

THE CASTING OF GERMAN SILVER.*

BY C. P. KARR.

GERMAN silver is a composition of nickel, copper, and zinc, in varying proportions. Its value in the arts depends upon its colour, lustre, hardness, tenacity, toughness, malleability, ductility, its machining qualities, its resistance to alkalies and acids. Generally speaking, it is manufactured in three different ways, German, English, and American.

In the German method the three constituent metals, nickel, copper, and zinc, are carefully weighed. A graphite crucible is used for the melting; in its bottom is placed first a layer of copper, then a layer of zinc, and then a layer of nickel, and this arrangement is continued until all of the copper is charged into the pot. One-third part each of the nickel and zinc is withheld until the contents of the pot are melted. The covering consists of charcoal. When the first charge is completely melted, the molten metal is thoroughly stirred with an iron rod, then the zinc and nickel are gradually added as fast as the fluid charge will absorb them, well stirred, and allowed to come to a pouring heat. A small excess of zinc is then added to replace the loss by volatilisation. For a rolled metal the charge is kept for some little time in a molten condition and then poured.

The English method is to melt all the nickel and copper and zinc at one fusion. The covering is coal dust. When melted, a small quantity of a previously prepared alloy of one part of zinc and one-half part of copper by weight is added, and finally about one-fifth by weight of the previous charge of zinc is added. The mass is then strongly heated until the proper fluidity is reached.

The American method consists in melting a previously prepared alloy of copper and nickel of the required proportions. The covering is charcoal. Then this alloy is remelted and the proper amount of zinc is added piece by piece, care being taken to preheat the zinc and to add it in such manner as to not chill the molten bath, or to melt the zinc in another pot at just melting heat and pour the molten zinc into the molten alloy of copper and nickel, stirring vigorously during the entire operation. Various modifications of the American method, as described, are in vogue in various large works where German silver is made on a large scale. For example, the nickel, granulated, is melted first, and brass—rolled or rod brass is best—which contains the requisite amount of copper, is added to the molten nickel, and if such brass does not add a sufficient quantity of zinc, the required amount is calculated and added subsequently. Another method is to use Monel metal as a base containing the requisite quantity of nickel, then the deficient copper is added, and finally the zinc, or a good rolled or rod brass may be added to the Monel metal to supply either all or a portion of the copper and zinc that may be lacking.

In the English method the alloy is tested by withdrawing a small ladleful from the molten bath, and if found porous, a fireclay pipe containing pitch is pushed down into the molten bath to deoxide the metal and restore it to a sound condition.

One of the great difficulties found in the preparation of German silver is to so unite its constituents as to avoid porosity and produce a homogeneous alloy. The high temperature required to melt nickel alone, accompanied by its affinity for carbon and nitrogen at a high temperature and its property of occluding both hydrogen and nitrogen within its pores has well nigh driven many ambitious founders into a state of despair. A good protection against these ills is to prevent the access of these gases to the metal by a protective covering and a deoxidising flux. Charcoal should not be used alone as a covering; broken glass accompanied by a small proportion of soda ash or calcined borax are much better. A good deoxidising flux is the proper use of zinc itself in the making of the alloy and in also adding a small amount of dry chloride of zinc just after skimming the pot preparatory to pouring, and this flux should be carefully stirred through the very hot mass.

Perfect castings have been secured by adding four ounces of cupro-nickel-vanadium to the molten bath, about five minutes before the heat is ready to pour. The best procedure is to have the cupro-nickel-vanadium either in a granulated form or broken into small pieces, wrapped in a piece of paper

* Paper read before the American Institute of Metals.

so as to keep the mass together, allow the little heap to become bright cherry red, and then push it down below the surface, and hold it there, with an inverted cupped disc, the handle to which is about 4ft. long. The mass is held down near the bottom of the pot until it is completely absorbed by the charge. Then gently stir with a pumping motion, and allow the charge to remain quietly for about five minutes, so as to give the vanadium a proper chance to perform its scouring and purifying action. The vanadium exerts no delerious action upon the texture of the crucible. When the metal reaches a clear, limpid state, as evidenced by its greater mobility, the heat is ready to pour. Lambent flames of zinc oxide flare up at the sides when the metal is in a perfect condition.

After the alloy is made the founder's chief trouble begins. Any alloy containing nickel chills with surprising rapidity, thickens by rapid oxidation, and its shrinkage, when reaching its freezing point, is beyond all precedent. To overcome its tendency to chill, its melting point must be materially reduced by the use of some alloy that will promote its fluidity; this may be done by the introduction of a small proportion of a previously prepared aluminium zinc alloy and is advisable where the castings do not have to sustain a hydraulic test. Where a hydraulic test must be borne, a previously prepared calcium-zinc alloy may be used with good results. To overcome its tendency to rapid oxidation on the surface of the bath, chloride of zinc in a perfectly dry state is almost a specific.

To overcome its excessive shrinkage, the runner on the gate must never be less than the maximum thickness or area of the maximum area of the shell of the casting. Sometimes in solid work the sprue head must weigh as much as the casting. While chloride of zinc as a flux will preserve the metal from surface oxidation, it will not protect the body of the molten charge from the absorption of such gases as oxygen, nitrogen, and sulphur; the only reagent which will reach these products is one that will either be decomposed by them when in a nascent state so as to act as a carrier for them and bring them to the surface to be absorbed in the slag, or some element which has a greater affinity for them than the basic metals in the pot. There are three elements which have a greater affinity for such gases than copper, nickel, or zinc, and these elements are zirconium, boron, and titanium and one element which acts both as a carrier of oxygen and has a strong affinity for nitrogen and sulphur, and that element is vanadium. At this point, however, I wish to emphasize the importance of using a pure product of cupro-vanadium; one having any aluminium, however small the quantity, is not to be recommended for valve work or other castings requiring a severe hydraulic test.

Having secured a perfect composition and skilful treatment at the melter's hands, the foundryman is still far from ultimate success. First the body of his mould must be an open sand, his facing must be of some fine moulding sand, which must be skin dried, and then the moulds must be smoked by a torch; where a heavy casting is to be made, even these precautions will not lead to success; his sprue head and main feed gate must be brushed down with graphite and smoothed down with a slicking tool. Now all of this will be of no avail unless the moulder has been careful to vent his mould properly, at all places where it is possible for the gas to become trapped or pocketed; furthermore, the cores should be made of white lake sand mixed with some approved core compound, the whole mass being skin-hardened by stale beer. In many cases even the core has to be vented. With all of these precautions the casting may prove worthless if the metal is not properly skimmed before pouring, and then poured with a uniformly steady stream and at such a rate as to keep the descending column full, so as to avoid spelter marks and cold shuts. To conclude, I would say that the art of making sound German silver castings is one that is accompanied by infinite precautions, painstaking details, and a devotion to thoroughness that knows no limitations.

The Concrete Institute.—At a recent meeting of this institute, Mr. J. M. Theobald read a paper on "Bills of Quantities for Reinforced Concrete," in which he reviewed the different forms of contract under which reinforced-concrete construction was carried out, and dealt with the details of the work, its measurement, and its pricing.

INDUSTRIAL AND TRADE NOTES.

The Use of Oil as Fuel in the United States.—Nearly 62,000,000 barrels of oil were, it is estimated, consumed as fuel in 1911 in the United States, as compared with 61,000,000 barrels in 1910.

Trade Circulars.—We have received from The Cruse Superheater Company, the Parsonage, Blackfriars, Manchester, an illustrated circular showing the arrangement of their patent superheater, with particulars of a test made by the testing staff of The British Engine, Boiler and Electrical Insurance Company. From the London Emery Wheel Company Perfection Works, Tottenham, London, N., we have received a circular describing and illustrating the Buess oil-fired crucible melting furnace.

Orders for Oil-engined Ships.—Messrs. Samuel, of London, have, we learn, placed an order for a large oil tank steamer with Messrs. Swan, Hunter, & Wigham Richardson, Ltd., Wallsend, to be fitted with Diesel engines, which will be made at the Neptune works of the firm, Low Walker. The same owners have also ordered a similar ship from Messrs. Armstrong, Whitworth. This vessel will be built at Low Walker, and her Diesel engines will be constructed by the Wallsend Slipway Company.

Wages Advanced in the Tube Trade.—At a meeting of the Wages Board of the Staffordshire and Midlands iron tube trade, held on the 6th inst., to consider a notice of advance served by the operatives, it was resolved to concede an immediate wages advance of 2½ per cent. on gas, water, and steam tubes from ⅛in. up to 6in. sizes, and a further 2½ per cent. at the beginning of February. The employés promised to hold a further conference before Christmas to consider a wages advance also on ⅜in. tubes and fittings.

Electrification of a London Railway.—The London and South-western Railway Company have decided to make a commencement with the electrification of their London suburban lines by converting 73 miles of single track on the circular route from Waterloo viâ Wimbledon, Kingston, Twickenham, and Richmond, back to Waterloo. The conversion of a further 100 miles of single track will follow in due course, but owing to the magnitude of the work it will be some little time before these further extensions can be put in hand. The company will adopt the direct-current third-rail system, and will have their own power-house, with substations.

Marine Oil Engines.—The Burmeister & Wain (Diesel System) Oil Engine Company are to commence the manufacture of oil engines at their works in Glasgow in February of next year. The company have at present orders for their Glasgow works to supply oil engines for six vessels. They have entered into a contract with the East Asiatic Company of Copenhagen to manufacture engines of 2,250 h.p. for the two twin-screw vessels which are to be built by Messrs. Harland & Wolff, and also to replace the present engines of three steamers of the company's fleet by motors of 1,600 h.p. In addition, they are to provide engines of 3,200 h.p. for the Atlantic transport liner which is to be built at Govan by Messrs. Harland & Wolff.

Diesel-engined Oil Tankers.—Messrs. Krupp recently launched at Kiel the first of the three oil tankers which they are building for the German American Petroleum Company. The vessel is driven by two sets of 6-cylinder Krupp-Diesel engines of 2,300 h.p. The scavenging pumps are worked off the middle crossheads, but the high pressure air for injection and manœuvring is supplied by independent compressors driven by separate Diesel engines. The problem of the auxiliary machinery has been attacked in such a manner that experience will be obtained with compressed air engines, steam engines, and electric sets, examples of each of these being incorporated in the design. At sea the exhaust gas is employed to heat the water for the heating of the ship. The vessel, which is of 7,700 tons carrying capacity, measures 400ft. between perpendiculars, 53ft. in extreme breadth, and 32ft. 4in. to the upper deck. The draught is 25ft. 3in.

North-eastern Electric Railway Extensions.—With a view to affording improved facilities for the development of the residential area of the Northumberland coast, served by their Newcastle and Tynemouth electrified lines, the North-eastern Railway Company are embarking upon a large scheme of alterations at Monkseaton, and also the construction of a new stretch of railway from Monkseaton to Seaton Sluice on the Northumberland coast. The existing Avenue branch line, which runs from Monkseaton to Blyth, is to be diverted into a new station to be built at Monkseaton and doubled for about half a mile, from which northward point a new railway, two miles in length, having intermediate stations at Briardene and Hollywell Bay, will extend coastwise to Seaton Sluice. A commencement will shortly be made with the work, which, it is estimated, will cost about £30,000. It is expected that these extensions will be ready for use by Easter, 1914.

Motors in Fishing Boats.—Captain J. R. M'Ewan, marine superintendent to the Fishery Board for Scotland, has presented an interesting report to the Board regarding a visit he paid to the Scandinavian Fisheries and International Marine Motor Exhibitions which were held in Copenhagen in July and August. In his general remarks he states that none of the methods shown for transmitting motor power to trawl winch or net hauling capstan would, in his opinion, prove satisfactory on board large trawlers or drifters. The general position seemed to be that for small and moderate-sized fishing boats, or as an auxiliary in the large East Coast sailing boats, motor power was highly desirable, and for this purpose a great variety of serviceable and suitable motor engines was available, but that it was extremely doubtful whether steam could be successfully competed with by oil motors in full-powered drifters and deep sea trawlers. This position was produced partly by the present uncertainty of future prices for oil fuel and also partly by the fact that it would be difficult for some time at least to get men who were competent to run a Diesel engine to go to sea in a fishing boat.

Agreements in the Shipbuilding Industry.—At a meeting of the Industrial Council, held in London on the 4th inst., Mr. I. D. Hebron, of the United Patternmakers' Society, and secretary of the Board of Conciliation for the patternmaking industry of the North-east Coast, expressed the opinion that it was desirable that an agreement in the shipbuilding industry on wages and hours should extend to the whole of the industry in a local area. He certainly thought that on all questions of wages and hours sectional agreements should not exist. In the past the men in his society (comparatively small in number) had suffered through being thrown idle by the action of another section of the shipbuilding industry. There was therefore the possibility of a small body of men taking action which would dislocate a whole industry with grave results. Witness said his society had rules for the restriction of overtime, and those rules had been proved to have a beneficial effect. With regard to agreements, he was not in favour of their containing any penal clause. He was in favour of a federation of the sections of the engineering trades to deal with the questions of hours and wages and general questions. As to the agreement which existed between his society and the employers, the right to strike had been virtually abandoned, inasmuch as the agreement provided for six months' notice to be given for the termination of the board which existed under the agreement.

Mining Methods in India.—An interesting account of mining conditions in India was given by Mr. J. R. R. Wilson, H.M. Inspector of Mines, Liverpool, in a paper read before the Yorkshire branch of the National Association of Colliery Managers. In India the miner had to deal with seams of coal ranging from 5ft. to 50ft. and 80ft. in thickness. Despite the maintenance of primitive methods in many mines, the output of coal had now reached 12 million tons a year. Progress was now being made, he said, in English mining methods. In many places they still saw coal being carried in baskets and dumped into railway wagons, whilst almost next door the most up-to-date electrically controlled screening plant was in operation. At many Indian mines the coal was still carried up fairly long inclines to the surface upon the heads of women and girls. The males got the coal and the females carried it. The women would carry for long distances a weight of 80lbs. upon their heads. In the Raniganj coalfield 24 hours shifts were quite common, though, of course, the men were not working all the time, but ate and slept and worked at will. The system probably arose from the fact that numbers of them lived a long way off and could not very well take the journey every day. Sleeping in the mines was very common, both on the part of the pieceworker and the day wage man. Fire damp could not yet be said to be one of the risks of Indian coalmining; its presence, however, had been felt at a few places where a moderate depth had been attained, necessitating the use of safety lamps. Though one could find in India examples of mining practice which belonged to the beginning of things, yet on the other hand, there were collieries which were a credit to the profession of mining engineering. The coal mining industry was steadily making progress, and the most backward were becoming imbued with the modern spirit. The Indian official was becoming educated in the principles of mining, and was attending classes and lectures with a regularity and zeal which he could commend to his white fellow student.

Strikes and Lock-outs in 1911.—The Labour Department of the Board of Trade has issued the 24th annual report on strikes and lock-outs and on Conciliation and Arbitration Boards in the United Kingdom in 1911. At the outset, Mr. George S. Barnes points out that the year 1911, like its predecessor, was marked by considerable industrial disturbance. The total number of workpeople involved in disputes was 961,980, which was the highest recorded in any year during the period 1893-1911, and the aggregate duration (10,319,591 working days) of all the disputes has been exceeded only in 1893, 1897, 1898, and 1908. Of the aggregate duration of disputes in progress in 1911 the transport trades accounted for two and three-quarter million working days, and the textile trades for one and a half million days, while a further two million working days were lost in 1911 by a coal mining dispute which commenced in 1910. The principal causes of disputes in 1911 were questions of wages and of trade unionism, the former involving 46 per cent. of all the workpeople directly affected by disputes and the latter 39 per cent. The general strike of railway servants and the lock-out in the cotton trade were responsible for the high proportion of workpeople involved in disputes in which the chief object was the assertion or defence of trade union principles. Settlements in the nature of a compromise were arranged in the case of 84 per cent. of the total number of workpeople directly affected by all disputes, less than 7 per cent. were wholly successful, and rather more than 9 per cent. were wholly unsuccessful. Conciliation or mediation entered largely into the settlement of the big disputes of the year, the total number of workpeople involved in labour troubles in which settlements were effected under the Conciliation Act, 1896, and in other ways, being 348,333. Settlements by arbitration affected only 7,435 workpeople. Many disputes were settled in 1911 by conciliation or arbitration without stoppage of work, the number of cases settled by Voluntary Permanent Boards of Conciliation and Standing Joint Committees showing an increase for the fourth year in succession.

The Commercial Development of China.—At the inaugural dinner of the British Engineers' Association, held in London on the 3rd inst., Sir Walter Hillier, K.C.M.G., C.B., late adviser to the Chinese Government, stated that he had been intimately connected with China for 45 years. The commercial changes that had taken place in China during this period had been conspicuous. Whereas in bygone years the Chinese merchant came to the foreign merchant with demands for the supply of his needs, the growth of trade and the increased competition of numerous rivals in the commercial world of the Far East had practically reversed the old order of things. Now it was the foreign merchant who had to seek out the Chinese buyer, and to seek him over wide areas which had been opened up by the continued and continuing spread of railway communication. The spread of railway lines had not only opened up new centres. It had created new demands, and to keep pace with these demands that were ever growing it was imperative that these new and widening fields of commercial enterprise should be exploited and watched by experts ready to take immediate advantage of the opportunities that presented themselves. The information supplied in Consular reports and Board of Trade journals was doubtless valuable enough, but it could not but be lacking in one respect—it was never up-to-date—and those who were on the spot had already seized opportunities which were brought to the notice of the British trading public many months after they occurred. Although British imports and exports still headed the list in the volume of Chinese trade, our lead was, he said, menaced seriously and in new ways in consequence of the greater energy and enterprise of our foreign competitors who realised apparently more than we had hitherto done the necessity for push and closer touch with the consumer. Our German competitors, to mention no others, seemed to be beating us in many lines. They did not beat us by the superiority of the appliances they supplied or necessarily in the matter of price. Their success undoubtedly lay in the enterprise which, with a few marked exceptions, was so much keener with them than with us. No one, surely, could blame our commercial rivals for their go-ahead methods, but it appeared to him that if we wanted to hold our own against them we must take a leaf out of their book. Above all, it was in their great capacity for putting into practical effect the policy of co-operating with each other for the promotion of their foreign business that the success of our foreign competitors had been achieved. With them it was not merely a question of co-operation between the manufacturers and themselves, but between the manufacturers, the banks, the railway and shipping companies, and the Government. Everyone concerned put his shoulder to the wheel in a combined effort for forwarding the trade of his country. If this Association could overcome the general condition of inertia as regards prospective opportunities that prevailed in Great Britain, so that we could bring our forces into line to fight our competitors with their own weapons, it would have accomplished a task that would amply justify its existence. Much has been written and said of late about the future of China. In spite of recent upheavals and present financial embarrassments the trade of China progressed merrily. She had not retrogressed, that was certain, and he firmly believed that not only would she continue to go forward, but that, sooner or later, she had a prosperous future before her.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Reversing gear for multi-cylinder internal combustion engines. Marks. 18715.
Oil engines of the Diesel type. Marks. 18802.
Spur-transmission gearing. Poppe. 22622.
Belts for transmitting power. Brown. 22623.
Mechanism for converting reciprocating motion into rotary motion and vice versa. Johnson. 22822.
Chain pulleys. Bell. 23647.
Power hammers. Universal Patents Bureau, Ltd. 25501.
Treatment of sulphide ores. Ashcroft. 25506.
Piston rings. Love & Brown. 25508.
Self-starter for internal-combustion engines. McHardy. 25700.
Valves for internal combustion engines. Nicholson. 25761.
Steam generators. Soc. Anon. des Etablissements Delaunay-Belleville. 25793.
Exhaust steam oil separator. Barker. 25821.
Steam generators. Sumner. 25822.
Stop-cocks. Maynard. 25842.
Clutches. Ellett. 25922.
Variable-speed friction gearing. Cole. 25928.
Driving chains. Rowledge, and Wolseley Tool and Motor Car Company. 25978.
Pipe couplings. Smith & Hillman. 25985.
Steam superheaters for locomotive boilers. Robinson. 26033.
Mounting of wheels and rotary devices on their shafts. Neate. 26165.
Rotary valves and valve gear for internal combustion engines. Whittaker & Whittaker. 26193.
Metal mixers and open hearth furnaces. Head. 26240.
Starting apparatus of internal combustion engines. Christensen. 26619.
Shaft bearing. Bell. 27142.
Carburetters. Spence. 28096.
Carburetters for internal combustion engines. Baldwin. 28175.
Turbines. Anderson & Ward. 28314.
Ammunition hoists. Sir W. G. Armstrong, Whitworth, & Co., and Murray. 28371.
Carburetter. Roots. 28691.
Utilisation of exhaust steam for heating purposes and for the production of power. Wharton, Hallowell, and Jones. 28841.

1912.

Internal-combustion engines. Potdevin. 338.
Rotary engines. Barry. 1111.
Internal combustion engines. Marshall. 1508.
Instruments for measuring changes in the speed or rate of change of the speed of moving bodies. Wheatley. 1591.
Valve gear casings of internal combustion engines. Calcott Bros., Ltd., and Calcott. 1607.
Starting mechanism for internal combustion engines. Allday and Simms. 1633.
Speed indicators for motor vehicles. Duncan & Elion. 2225.
Internally-fired boilers. Casmey. 3876.
Method of jointing or welding articles of metal. Nuttall. 4098.
Automatic shut-off valve for steam. Williams. 4227.
Railway signalling apparatus. McKenzie & Holland, Ltd., and Edmonds. 4759.
Tube rolling apparatus. Pittsburg Steel Products Company, and Selkirk. 4795.
Ships' steering gears. Clay. 5737.
Valves for internal-combustion engines. Sears. 6277.
Combined elastic clutch and engine starter. Reagan. 7785.
Axle boxes for railway vehicles. Wood. 7831.
Method of and apparatus for superheating steam. De Boer. 7899.
Turbines. Upson. 8350.
Belt shifter. Hallot. 8430.
Grinding machines. Royston. 8708.
Centrifugal pumps and compressors. Huguenin. 8713.
Distillation of bituminous coal. Glasgow. 9292.
Motor vehicles. Hoadley & Hoadley. 9973.
Process for improving the properties of ingot iron. T. H. Goldschmidt Akt.-Ges. 10117.
Cylinder head for internal combustion engines. Lindemann. 10258.
Exhaust silencers for internal-combustion engines. Clarke. 10306.
Stop motions for tool feed mechanism. Howard & Usher. 10735.
Internal combustion engines. Nelson & Nelson. 11463.
Wrenches. Johnson. 11579.
Signalling on railway and tramway vehicles. Rowntree. 12017.
Fuel spraying apparatus for internal-combustion engines. Hamill. 12115.
Apparatus for producing air gas. Mayer & Holwech. 12369.
Devices for testing the tension of belts. Thompson. 12552.
Railway track points. Stahlberg. 12903.
Nut locks. Frank. 13964.
Shaft couplings. Boult. 15172.
Airships and aeroplanes. Wilson. 15754.
Gas measuring instruments of the wet-meter type. Aron. 15959.
Roller bearings. Jones, & Kynoch, Ltd. 17528.
Starting and charging mechanism for internal combustion engines. Moore, and Ambrose Shardlow & Co. 17531.
Flying machines. Von Keissler. 18171.
Steam heating apparatus for railway carriages. Earl. 18753.
Band sawing machines. Noble & Lund 21387.
Explosion motors. Wagner. 22992.

ELECTRICAL, 1911.

Electric lighting of vehicles. Compagnie Internationale d'Electricite Soc. Anon. 25331.
Electric torsion dynamometers. Lux. 25337.
Insulation of electric coils. Pollak. 25672.
Safety devices for electrical installations. Dierman. 25776.
Apparatus for measuring, indicating, and determining the charges incurred by a consumer of electrical energy. Murray. 26426.
Control of electric motor generator sets. British Thomson-Houston Company, and David. 26863.
Electrodes for arc lamps. British Thomson-Houston Company. 27620.
Dynamos for use in electric generative systems of motor vehicles. Brooks & Holt. 28137.

1912.

Electric fuses. Wordingham & Grote. 1389.
Arc lamps. Prestwich. 1980.
Means for governing the speed of alternating current commutator machines. Jacoby. 3007.
Dynamos of the homopolar type. British Thomson Houston Company. 4186.
Switch locking arrangements on switch boards used on motor vehicles. Vandervell & Midgley. 4682.
Telephone metering systems. Boult. 5972.
Remote controlled electric switches. Fairweather. 10835.
Means for attaching electric wires and cables to insulators. Taylor. 15324.
Circuit connections for alternating-current commutator motors. Siemens Schuckertwerke Ges. 16790.
Automatic sectionalising devices for electric distribution systems. Hawkins. 21261.

METAL QUOTATIONS.

TUESDAY, DECEMBER 10TH.

Aluminium ingot	90/- per cwt.
" wire, according to sizes, &c. ......from	112/- "
" sheets " " ...... "	120/- "
Antimony ......£39/-/- to	£40/-/- per ton.
Brass, rolled	$9\frac{1}{8}$d. per lb.
" tubes (brazed)	$11\frac{1}{2}$d.
" " (solid drawn)	$9\frac{3}{4}$d.
" " wire	$9\frac{1}{8}$d.
Copper, Standard	£75/12/6 per ton.
Iron, Cleveland	67/6 "
" Scotch	73/6 "
Lead, English	£18/10/- "
" Foreign (soft)	£18/2/6 "
Mica (in original cases), small	6d. to 3/- per lb
" " " medium	3/6 to 6/- "
" " " large	7/6 to 11/- "
Quicksilver	£7/8/6 per bottle
Silver	$29\frac{11}{16}$d. per oz.
Spelter	£26/10/- per ton.
Tin, block	£225/10/- "
Tin plates	$15/4\frac{1}{2}$ "
Zinc sheets (Silesian)	£29/17/6 "
" (Stettin; Vieille Montagne)	£30/5/- "

The British Electrical and Allied Manufacturers' Association (Incorporated).— The annual general meeting of this association will be held in the lecture theatre of the Institution of Electrical engineers, Victoria Embankment, W.C., on Friday, January 24th, 1913. The annual dinner of the association will be held in the evening of the same day.



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Young Engineers and Shop Experience.

If the present generation of young engineers do not improve on those of the last it will not be for lack of efforts on their behalf. Never has greater sympathy or greater desire been shown to help those who are worthy. In this respect they are more happily situated than their immediate predecessors who, armed with the new scientific knowledge that promised to profoundly modify engineering materials and methods, had yet to tread close on the heels of generations trained in "rules of thumb," and saturated with the lessons, and in some cases it may be the prejudices of experience. It is hardly to be wondered at that their new-fangled ideas were then received by seniors with contempt and a degree of resistance if attempts were made to carry them out, that made success difficult, if not impossible. Though a taint of this attitude still lingers in some works it is happily passing away. The march of science has been too rapid and overpowering to be stemmed by any "old fogey" broom, and no manufacturing industry can prosper or retain supremacy nowadays that does not invoke its aid to the fullest extent. But if prejudice often acted as a barrier to the introduction of improvements it should not be forgotten that it rested on a foundation of several generations of experience, to which the newer school did not always do justice, as its best survivors to-day would, doubtless, admit. Experience, and especially engineering experience, is expensive, and the majority of the lessons which have to be well learned before the student is of much value in an engineering works cannot be taught in a college. The perception of this fact has led to considerable amendation of ideas in recent years regarding what may, and what may not be acquired during student days. If the "old practical man" who disdained books and college learning was lacking in many things necessary for the conduct of a workshop on modern lines, his successor finds that his equipment in respect to workshop methods, experience, and practice is still

as necessary, and can only be got in the same way, slowly, and by daily contact with difficulties. As this is the most essential of qualifications for aspirants to positions of high responsibility in engineering works, so also is it the most difficult to acquire. How to ensure it is a problem easier to propound than to solve, but the thoughtful and suggestive presidential address of Sir A. Trevor Dawson to the Junior Institution of Engineers may be commended to both young and old as at least an earnest attempt in this direction.

If the possibility of epoch-making inventions in some directions appears to the budding engineer to be ended, let him not imagine that scope for improvement is curtailed, or that ingenuity is not required to effect them. Each extension of knowledge widens contact with the unknown, and demands further experience of those who move forward. In no direction is this more forcibly shown than in the application of science to engineering. Progress has been mainly the outcome of its concentrating knowledge on special problems, and to maintain it requires ever-increasing experience. This is the text which Sir A. Trevor Dawson amplified in the course of his address, and especially as regards its bearing on younger men, to whom also he urged a plea for a gentle restraint upon that characteristic of youth, "impatience," which, valuable as it is as an incentive to progress, is liable to focus itself too much on the immediate prospect, and in so doing overlook the more profitable, though more distant view. This is a difficulty whenever a prolonged training is called for, and one over which circumstances in many cases prove too strong. Opportunities for many kinds of experience are rare, and can only be afforded to a favoured few, and under conditions which will assure a profit to those who grant the privilege. Hence, if a youth desires experience in a new department he must accept a lower remuneration until his proficiency warrants its former level. The change might probably be wise, and a good investment in the long run, but few are able or care to make the immediate pecuniary sacrifice for the chance of a distant reward, and yet at no time has the demand, or the reward for combined scientific knowledge and practical experience been greater than to-day, and by experience we mean not merely knowledge of engineering materials and methods, but what is rarer still, knowledge of human nature and how to control men. It cannot be learned from books, and the first lesson, "How to control oneself," is perhaps the hardest of all.

Of one thing, however, any aspirant in this direction may be sure — he will not achieve success in its fullest sense unless he inspires a sense of loyalty in the assistants and workmen round him by the pre-eminence of his own experience and attainments. This brings us to the old question, How to select and train the heads of engineering works. The statement that with the increasing stress of international competition we require the best mental capacity the nation possesses for filling such positions needs no labouring. At present both training and selection are determined by many chance factors in the rough and tumble of existence and probably lead to the overlooking of much latent talent. But we do not see how to greatly improve the present methods of selection. Sir A. Trevor Dawson suggests an extension of State educational facilities in the form of scholarships, which would permit of promising youths acquiring shop training and experience from which shortage of financial resources would otherwise preclude them. But this does not seem to carry us very far, notwithstanding our sympathy with the object. Examination tests, we know, are sometimes disappointing even when restricted to book knowledge, and, we fear, would be more so if applied to the measurement of the complex abilities that go to make a successful engineer, though it is true the creation of a grade of what he terms "staff officers," who have graduated through a course of workshop training, designed to allow of the acquirement of practical experience, would enlarge the area of choice. It is true also that shop experience to be of real value should be acquired in the early stage of a mechanical engineer's career. If contact with the workshop is deferred till he is 21 or 22 years of age his chance of deriving the benefit from it is greatly diminished. At that age he is less tolerant of its rough and tumble experience, his mind is less plastic and inclined to be prejudiced with ideas which make it difficult to realise that the craftsman has much to teach him. Apart from which he cannot get into that sympathetic touch with workmen which is possible at an earlier age, and in consequence may later on be at a disadvantage in negotiating with them. Shop experience alone, even when of the widest character, is, of course, not sufficient. Its blending with college training on some system is necessary, while beyond this, when the combined training is concluded, is the need for a continuation of experience to qualify for higher posts. This, it is suggested, could be secured by firms undertaking to take such apprentice students into the works for a further high-class training at a good wage. At this point again we confess our experience of human nature and knowledge of inexorable economic laws make us see many difficulties in the working of such scholarship schemes, deeply though we sympathise with the end, and agreeing with the author of the address that our "most clamant national need is for high-grade intellect to create new appliances, and perfect existing designs, both in regard to durability and economy so that we may hold our own with all competitors."

North of England Institute of Mining and Mechanical Engineers.—A general meeting of this Institute was held at Newcastle on Saturday last. The President (Colonel W. C. Blackett) presided. The discussion took place upon several papers that had been read at previous meetings, viz., "The Ignition of Coal-gas and Methane by Momentary Electric Arcs," by Prof. W. M. Thornton; "Electrically-driven Winding Engines in South Africa," by Mr. A. W. Brown; and "A Photographic Method of Rapidly Copying out Pay-notes in use at Throckley Collieries," by Messrs. T. V. Simpson and G. W. Bell. The Hailwood gas-cap observation was exhibited, described, and demonstrated, as were also several types of electric safety lamps.

Mining Electrical Engineers.—The monthly meeting of the West of Scotland Branch of the Association of Mining Electrical Engineers was held on Saturday last in the Royal Technical College, Glasgow. An interesting paper was read by Mr. Sidney A. Simon, B.A., on "Variable Speed Alternating-current Motors." At the outset the author explained that one of the chief arguments raised against the more extended use of 3-phase alternating current had been the difficulty of obtaining efficient speed control of the motors. A great amount of ingenuity and thought had been expended on trying to overcome this drawback in a system which otherwise possessed so many eminent advantages. While not holding a brief for the universal adoption of 3-phase alternating current, knowing that there were many applications of electric power for which direct current was undeniably superior, his (Mr. Simon's) intention in his paper was to describe the most important of the methods of 3-phase speed control which had been successfully developed.

REPEATED STRESS TESTING.

Two papers on this subject were presented by Mr. J. B. Kommers, of the University of Wisconsin, at the last meeting of the International Association for Testing Materials. In the first paper the author said that any test similar to that of Wöhler was not expeditious enough to be used commercially, and for that reason it seemed desirable to investigate the important factors which might prove satisfactory for commercial purposes. It was therefore decided to try one of the commercial machines already on the market rather than design a new one. After considering the various machines available, the Landgraf-Turner alternating-impact machine was chosen, since for this machine the specimen required was simply a round rod, ⅜in. diam. and about 8½in. long; also, both ends could be tested, giving two results for each specimen. Furthermore, this machine could be quite easily modified to do the work required.

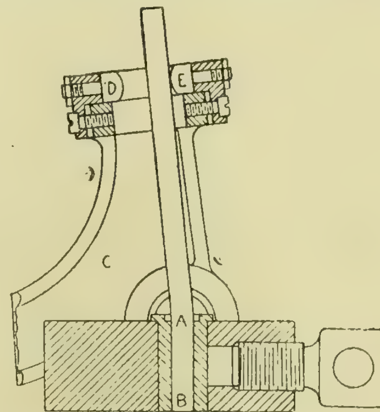
In this machine, shown in the accompanying cut, the specimen is held vertical as a cantilever beam and is deflected on either side of its neutral position, thus subjecting the specimen at A first to tension on one side and to compression. The specimen is held firmly in the vice at A B over 1½in. of its length. The rocker arm C causes the specimen to be deflected. The top of this rocker arm is fitted with two hardened steel hammer dies D and E. It will be seen that when the hammer dies are more than ⅜in. apart the specimen will receive a certain amount of impact before it is deflected. The free length of the specimen from the top of the vice to the hammer dies is 4in. The frame carrying these dies may be adjusted so that the amount of deflection is the same on either side of the neutral position of the specimen. The rocker arm which deflects the specimen is driven by a crank. In the experiments it was necessary to change the stroke of the machine, and this was done by providing suitable double eccentrics on the crank shaft. By this means it was possible to vary the deflection while the distance between the hammer dies D and E remained constant. Also by providing various sets of hammer dies it was possible to vary the distance between the hammer dies.

Since hundreds of specimens were to be tested, the experiments would have been expensive if each specimen had been turned up in a lathe. To eliminate this expense it was decided to make use of ⅜in. cold rolled steel which had been annealed. The steel was annealed at a red heat in a gas furnace. As a check on the uniformity of the steel, three tensile tests were made on each batch of steel after it had been annealed. It ran about 39,600lbs. yield point and 60,000lbs. per square inch ultimate strength, with 38 per cent. elongation on 2in. and 63·5 per cent. reduction of area. It was found that any slight change in the diameter of the specimen did not seem to affect the results. The greatest variation of this kind was about 0·004in., while the average variation was probably half that amount.

In the preliminary tests it was found that shortly before complete rupture the specimen seemed to weaken or give way. This was generally quite distinctly noticeable by the change in the "song" of the machine. This matter was further investigated and it was found that when a specimen was taken out of the machine just after this "weakening" it showed distinct cracks or openings on both sides at the grips. Furthermore, when this "weakening" stage was passed, the specimen could be completely ruptured by bending it forward and back by hand. When the other end of the specimen was tested and taken out of the machine just before "weakening" was expected, it was found that the specimen showed either no sign of cracking or merely an incipient crack on one side. Moreover, in this condition the specimen was altogether too strong to be ruptured by hand. Further experiments along this line seemed to demonstrate that the point of "weakening" was really the important point of failure, and that after this stage was passed the specimen was held together near the middle of the cross-section by a small strip of metal which had no real strength. For instance, when there was a certain amount of impact the upper part of the specimen would soon become loosened, due to the blows received, while when there was no impact it might require from 25 to 100 additional cycles after "weakening" in order to produce final rupture. For these reasons it was thought that a fair comparison should depend upon the real point of failure, which was the point of "weakening," and the results were based upon this consideration.

The experiments thus far made might be summarised as follows: (1) A very important factor in a repeated-stress test similar to that performed by the Landgraf-Turner machine was the amount of deflection which the specimen received. When the deflections were less than 0·30in. the change in the number of cycles required for rupture was very great, even for small changes in the amount of deflection. (2) Impact applied to the specimen as in the Landgraf-Turner machine had practically no effect upon the number of cycles required for rupture. (3) At speeds of about 700 cycles per minute the number of cycles for rupture was slightly less than at speeds of about 150, but for small changes of speed this effect was practically negligible. When the deflection was small the results on the same material did not seem to be as uniform as when the deflection was about 0·30in. or a little more. (4) The condition of the surface of the specimen had an important effect upon the number of cycles required for rupture.

In the second paper the author pointed out that one of the factors to be noted and reported in a repeated-stress test was the character of the fracture. Practically all those specimens which gave high results in the repeated-stress test had "fine" or "very fine" texture at the place of fracture. Specimens like wrought iron and cast brass, which gave very poor results, showed coarse fractures. The uniformity of manufacture of any particular kind of steel was, he said, well brought out by



Landgraf-Turner Alternating Impact Testing Machine.

the repeated-stress test. A homogeneous product, for instance, should give results in the repeated-stress test that varied but little from each other; and results on the same steel (or at opposite ends of the same specimen) that showed a great variation might rightly be looked upon as indicating that the steel was not as uniform as it should be.

In choosing the machine to be used in a standard repeated-stress test it was, he observed, undoubtedly of great importance that it be one which would allow of exact adjustment, so that the amount of deflection might be kept the same within very small limits. Even small changes in the deflection of the specimen caused great changes in the cycles required for rupture; in fact, this factor seemed to be more important than any other. The Landgraf-Turner machine was faulty in this respect, for the reason that there was no easy way of adjusting the hammer dies accurately. It was therefore almost impossible to get the machine adjusted the same way after new hammer dies had been put in or some equivalent change made. In a standard test, also, all specimens should be of the same size, and should preferably be first turned up in a lathe in order to obtain straightness. The specimen might then be ground to size, as had been previously suggested. The gripping devices should be such that there would be no possibility of the specimen slipping in any way. The author was at present designing a machine which he thought would fulfil the conditions which the experiments showed should be embodied in a repeated-stress testing machine.

Failure of a Steam Pipe on the "Lusitania."—Three men working on the Cunard liner "Lusitania" were, on the 10th inst., injured by the bursting of a steam pipe. The vessel was lying in the Huskisson Dock, Liverpool, taking in cargo preparatory to sailing, when the pipe carrying steam to the winches on the forecastle-head burst.

RECENT DEVELOPMENTS IN CURTIS STEAM TURBINES.*

BY R. F. HALLIWELL.

As a preliminary to a description of modern practice in the manufacture of steam turbines of the Curtis type, it will perhaps be desirable to investigate the particular points in which this turbine differs from others. The feature which especially distinguishes the Curtis turbine is the employment almost throughout of the compound impulse wheel, having two or more rows of rotating buckets on each wheel, as shown diagrammatically in Fig. 1. The reasons which have led to the adoption of this form of construction in preference to the single impulse wheel will now be dealt with. From the velocity diagram for a single impulse wheel, given in Fig. 2, it will be seen that to completely absorb the energy of the issuing jet it is necessary for the blades to have a velocity nearly half that of the steam. With any considerable difference in pressure between the entrance to and exit from the nozzle, the velocity reached by the steam is very great; for instance, if expanded from 150lbs. pressure to 28in. vacuum, the velocity attained would be about 4,000ft. per second, thus a blade velocity of about 2,000ft. per second would be necessary for a single impulse wheel to operate successfully between ordinary limits of pressure with one set of blades. The highest peripheral speed which it is possible to employ is probably found in the 300 h.p. De Laval turbine, in which with a 30in. wheel running at

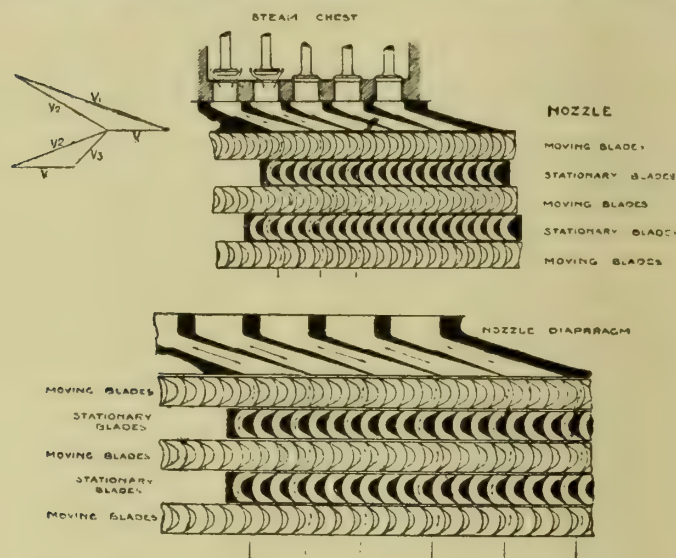


FIG. 1.—DIAGRAMMATIC ARRANGEMENT OF BLADING, CURTIS TURBINES.

10,000 revs. per minute, a velocity of over 1,300ft. per second is reached. Even this velocity is exceptional, and is only made possible by considerable expense in material and construction, and it is only in small units that the commercial advantages of the single impulse wheel outweigh the drawback of the limited efficiency due to insufficient bucket speed.

A natural method of reducing the velocity of the steam jet is by dividing the pressure drop between several stages in a manner analogous to that employed in compound reciprocating engines, and the number of stages necessary to obtain the desired results may be easily determined. Since the kinetic energy of the steam varies as the square of its velocity, if the pressure drop sufficient to produce a velocity of 4,000ft. per second is divided between four stages, a velocity in each stage of 2,000ft. per second would be obtained, and to come down to a velocity of 1,000ft. per second no less than 16 stages would be necessary. As the desirable blade velocity with ordinary materials and methods of construction does not much exceed 600ft. per second, the number of stages in this type of turbine, which is generally known as the Rateau, is always considerable.

The velocity diagram for a Curtis wheel with two rows of buckets is shown in Fig. 3, and it will be seen that with an initial steam velocity equal to 2 V, and a bucket speed, as in the previous case of $\frac{V}{2}$, the steam velocity leaving the first row of blades will be approximately equal to V; if this steam is suitably directed by stationary blades upon the second row of blades, its remaining energy will be nearly all absorbed by this row, leaving a final velocity of practically nothing. It is therefore evident that theoretically considered a double row of rotating blades in a Curtis stage can deal with steam of twice the velocity or four times the energy compared with a single row, or in other words, a turbine with the two-row combination need have only one quarter the number of stages necessary with an ordinary single row impulse turbine to obtain the same efficiency.

Consideration of this fundamental fact clearly shows the difference, which at first glance is not so very apparent,

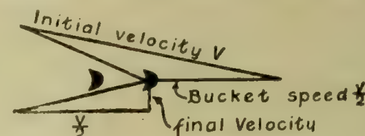


FIG. 2. VELOCITY DIAGRAM, SINGLE-IMPULSE WHEEL.

between a Curtis stage consisting of nozzles, a first row of moving blades, stationary or intermediate blades, and a second row of moving blades, and two simple stages, each made up of nozzles, and a row of moving blades. Each has the same number of similar parts, but while the latter distributes the work between the two stages by means of a division of pressure drop, the former accomplishes a similar distribution of work between the component parts by means of fractional absorption of an original high velocity.

A similar line of reasoning would show that theoretically a three-row combination would have an energy extracting capacity nine times that of a single-row wheel, and so on, but unfortunately, practical experience has proved that this is not realised completely, and frictional losses and eddies in the buckets, as well as the difficulty of arranging for the great increase in area required, owing to the low final velocity compared with the initial velocity, render the three-row combination the limit to which this principle may be usefully extended under ordinary circumstances. On the whole it is found that the best results with ordinary speeds are obtained with only two rows of moving blades per stage, but that if the speed is low compared with the output, it is advantageous to adopt three rows per stage. Further than this it rarely pays to go, except in some small turbines for driving pumps and the like, in which small size and cost are of primary importance.

Pressure and velocity curves for a five-stage turbine, with two rows per stage, are shown in Fig. 4, which perhaps gives a clearer idea of the combination of compound velocity and pressure stages than anything else can do.

The problem of designing the nozzles and buckets for a compound velocity stage is considerably more complex than for a simple impulse stage, and it has been found necessary to

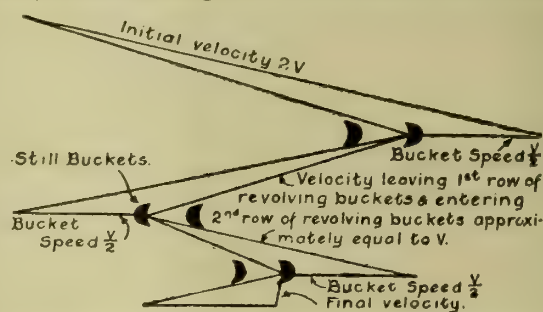


FIG. 3. VELOCITY DIAGRAM, CURTIS WHEEL, WITH TWO ROWS OF BUCKETS.

modify the designs based on purely theoretical considerations very considerably as a result of practical experience, with the consequence that the compound velocity stage has suffered from undeserved condemnation at the hands of those who have not carried their experiments far enough in the right direction. For instance, it has been definitely asserted by upholders of the simple stage that the maximum efficiency of the compound stage is only 67·5 per cent. with two rows of blades, and 52·5 per cent. with three rows of blades. That such statements are incorrect is obvious when the over-all thermal efficiencies of this type of turbine, as tabulated further on, are considered. As the losses to be taken into consideration when converting bucket efficiency into total thermal efficiency are rotation losses, bearing friction, and generator efficiency, and as these will amount to quite 10 per

* Paper read before the Manchester Association of Engineers, December 14th, 1912.

cent. of the full load output in turbines of medium size, it is evident that the compound stage has a much higher bucket efficiency than has been stated, and that such superiority of the simple stage is not borne out in practice.

As showing the bucket efficiencies which may be expected with two and three row combinations under average conditions, the curves in Fig. 5 have been drawn out, but it must be borne in mind that each case has to be considered by itself,

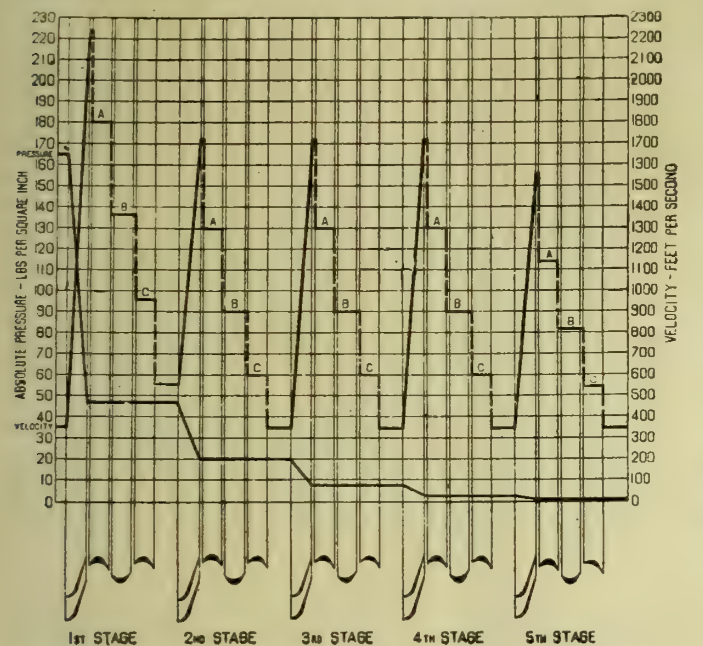


FIG. 4.—PRESSURE AND VELOCITY CURVES, FIVE-STAGE TURBINE, WITH TWO ROWS PER STAGE.

as with various conditions of energy available, and bucket speeds, the efficiency obtainable will differ from the curves, in some cases being better and in others worse. That the compound stage is not quite so black as some would have us believe, is fairly evident when it is considered how many builders of other types have adopted it with success in the first stage of their turbines.

That this simple impulse stage has a slight advantage in bucket efficiency is not denied, but unless one is prepared to accept the additional cost and complication attendant on the increased number of stages necessary, and unless the steam conditions are favourable to the attainment of the utmost economy, a departure from the simplicity and compactness of the compound velocity stage does not seem to be warranted for the sake of a possible small gain in thermodynamic efficiency. Apart from reasons of efficiency, however, it is sometimes desirable to adopt to a certain extent the simple stage. It has been previously stated that one of the difficulties in connection with a compound stage is the provision of the necessary increase in area, due to the comparatively low final velocity.

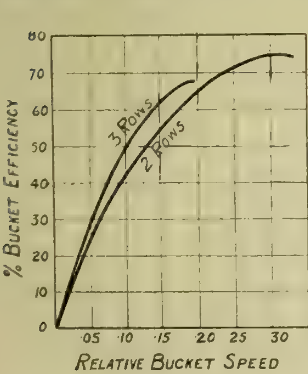


FIG. 5.—BUCKET EFFICIENCIES, TWO AND THREE-ROW COMBINATIONS.

With turbines of moderate output compared with their size, this difficulty is not noticed, but when large outputs are to be dealt with, even the two-row stage becomes unwieldy towards the exhaust end, and it is advantageous to use single-row wheels for the last or more stages, depending on the volume of steam to be accommodated.

Having thus briefly considered the main principles of the Curtis turbine, it may be of interest to study the leading mechanical features of these turbines, as made by the British Thomson-Houston Company, Ltd., Rugby. As is well known, these turbines, as first built in this country, were made with a vertical shaft, the generator being placed above the turbine, the whole rotating weight being carried on a film of lubricant delivered at high pressure between the faces of the footstep bearing. Although the vertical shaft arrangement proved itself to be most satisfactory in running, it was found that for small isolated units the cost was too high, due to the expensive accessories, and for large units an excessive amount of head room was necessary, but not generally available in this country. The horizontal arrangement also presents considerable advantages in accessibility, and in the more favourable position of the generator. The consequence is that at the present day practically all Curtis turbines made in this country have horizontal shafts, vertical turbines being

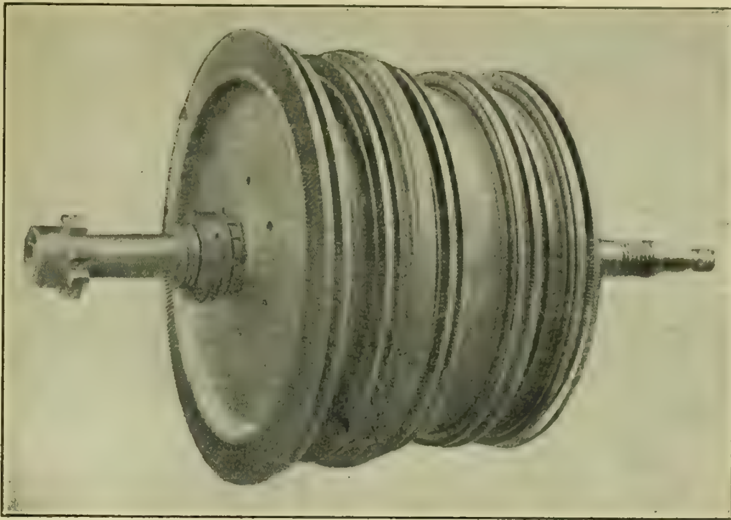


FIG. 6.—ROTOR OF CURTIS TURBINE.

only used where, on account of the limited floor space available, no other form of turbine of equal capacity could be installed. The following description, therefore, must be understood to apply to the horizontal turbine.

British Thomson-Houston turbines and generators are practically all of the four-bearing design, the turbine and generator having separate shafts, each with two self-aligning bearings (Fig. 6), the two shafts being connected by a flexible coupling (Fig. 7). Although there is no doubt that it is possible to obtain satisfactory operation with the three-bearing design favoured by some makers, if great care is taken to provide very solid foundations, it is considered that the advantage of being able to balance the rotors independently on their own complete shafts, together with the easier erection, more than compensates for any slight saving in cost and space due to a three-bearing design. Owing to the small

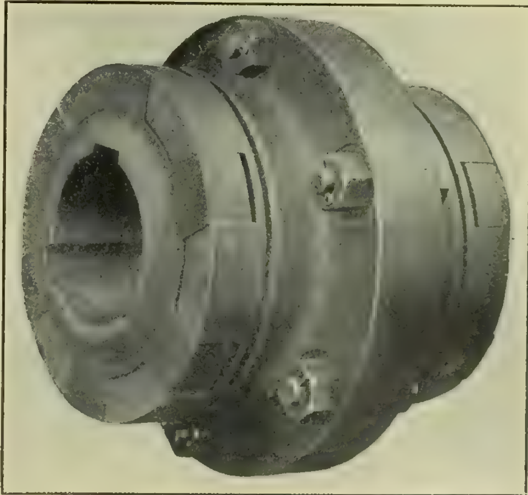


FIG. 7.—FLEXIBLE COUPLING.

number of stages used the centres of the turbine bearings are comparatively short, and the shafts are always designed to have a critical speed well above the running speed, thus avoiding the danger and risk of damage entailed by running through the critical speed. The bearings are lubricated with oil supplied under pressure. On the smaller turbines up to 2,000 kw., the bearings are fitted with oil rings to lubricate the bearings at starting up, but the larger turbines where bearing pressures are higher, are fitted with an auxiliary oil

pump, either hand or steam, for starting purposes. A diagram of the lubricating arrangements is given in Fig. 8.

The thrust bearing screws into an extension of the governor end bearing which ensures its perfect alignment, and consists of white metal lined collars embracing grooves turned in the shaft. Oil is delivered at the bottom of the grooves and, passing across the radial thrust surfaces, escapes at the outer periphery. It should be noted that in the Curtis turbine, as in other impulse turbines, the axial thrust is quite small, owing to each wheel revolving in a chamber having an equal pressure on both sides of the wheel. What small thrust there is, is principally due to friction of the steam on the blades, and to differences in the diameter of shaft where it passes through the diaphragms and casing. The thrust bearing can be adjusted whilst running, if required by means of a worm shaft, which rotates the bearing and screws it further into or out of the part into which it fits.

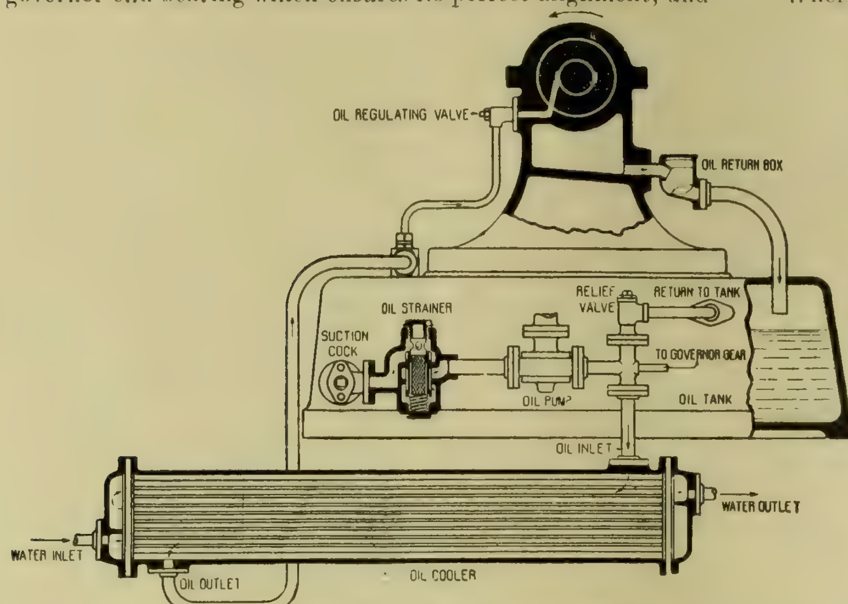


FIG. 8.—LUBRICATING ARRANGEMENTS, CURTIS TURBINES.

Where the shaft passes through the ends of the casing carbon packing is fitted, as shown in Fig. 9, which also shows the thrust collars and emergency governor, this packing consisting of segmental rings of carbon embracing the shaft, and encircled by thin bronze bands and garter springs. The rings are steam packed, the space inside the outer ring being maintained at slightly above atmospheric pressure, pipes being provided to lead away the surplus steam should the pressure in the casing be above that of the atmosphere, and to supply the necessary sealing steam should the pressure be below the atmosphere.

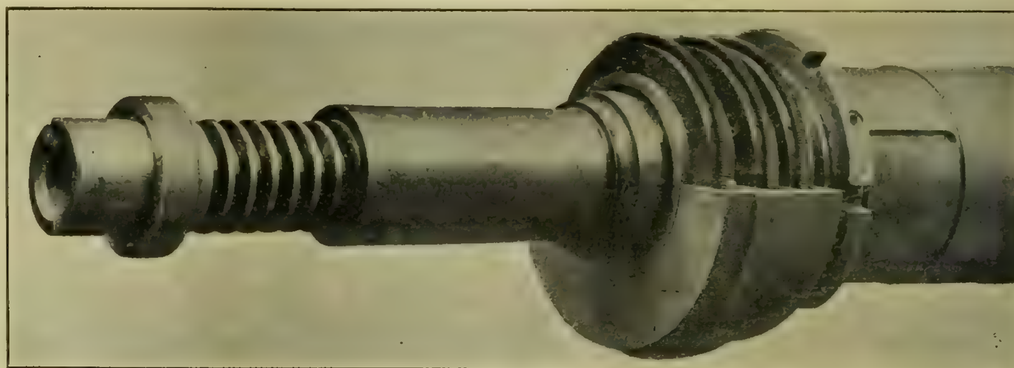


FIG. 9.—PART OF SHAFT OF CURTIS STEAM TURBINE, SHOWING CARBON PACKING.

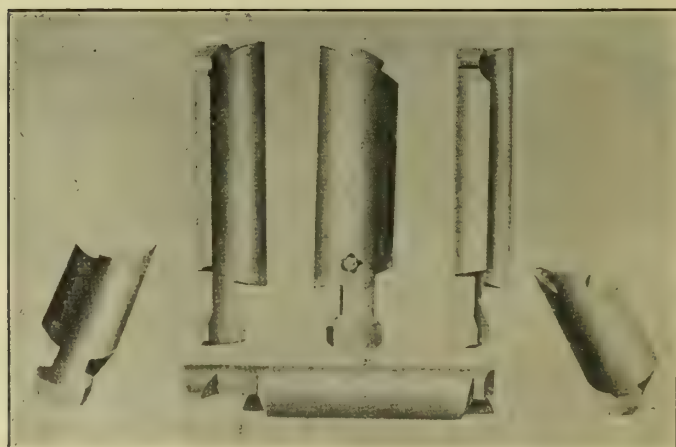


FIG. 10.—BLADES OF CURTIS TURBINES.

Where the shaft passes through the diaphragms a different design of shaft packing is used, consisting of an internally-grooved ring split into three or more parts, and pressed inwards by springs. This ring fits between side plates provided with annular shoulders, which prevent the packing ring closing inwards on to the shaft more than a certain amount, but at the same time give it perfect freedom to move outwards. The packing ring is made to originally fit the shaft tightly, but owing to the contact surfaces being quite small and the ring not being rigidly held, the packing is quickly worn away, and a minimum and permanent running clearance is obtained.

The wheels are made of high tensile steel, very accurately machined all over, each wheel being carefully balanced statically after blading, and before assembling on the shaft. They are provided with dovetailed grooves in the rim to receive the blades. The section of the wheels has to be very carefully calculated to give a uniform stress without undue expansion of the hub at high speeds if trouble with loose wheels is to be avoided.

The blades illustrated in Fig. 10 are generally made of drawn phosphor-bronze, this material having proved itself the most satisfactory for the purpose. The roots of the blades are milled to a dovetailed shape to fit into grooves in the rim of the wheel, and in each groove two gaps are cut on opposite sides for inserting the blades, which are pushed along the groove with spacing blocks between, until the groove is completely filled with the exception of the two gaps, the gaps



FIG. 11.—SHOWING METHOD OF FIXING THE BLADES AND BANDS OF CURTIS TURBINES.

being then closed by filling-up pieces provided with tails, which pass through holes in the rim of wheel and are riveted over at the back. The stationary buckets or intermediates, formed in the same way, are secured in a similar manner to the intermediate holders, which are segmental pieces fastened



Fig. 12.—Nozzles of Curtis Turbines.

either to the casing or the diaphragm. Both the rotating blades and the intermediates are closed at their ends by bands consisting of thin steel strips fitting over projections on the ends of the blades, which projections are riveted over on the outside of the band. The fixing of the blades and bands is

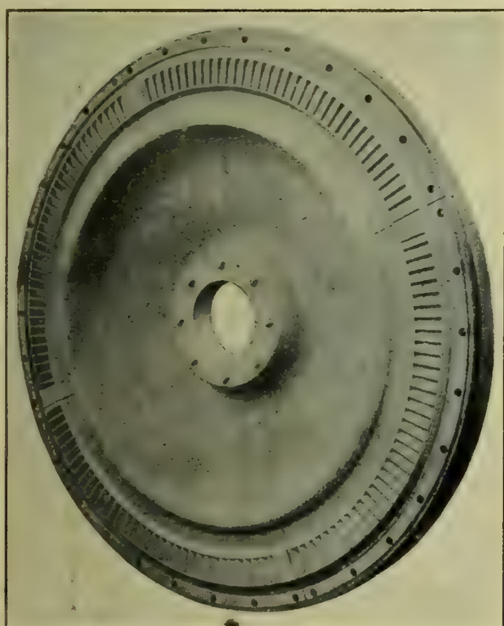


Fig. 13.—Nozzles of Curtis Turbines.

shown in Fig. 11. As a check upon the accuracy of workmanship each completed turbine rotor is run up to at least 25 per cent. over speed, and is then carefully examined.

The nozzles which direct the steam on to the first row of rotating blades, and which are illustrated in Figs. 12 and 13, are formed of nickel steel plates cast into an iron frame, bolted

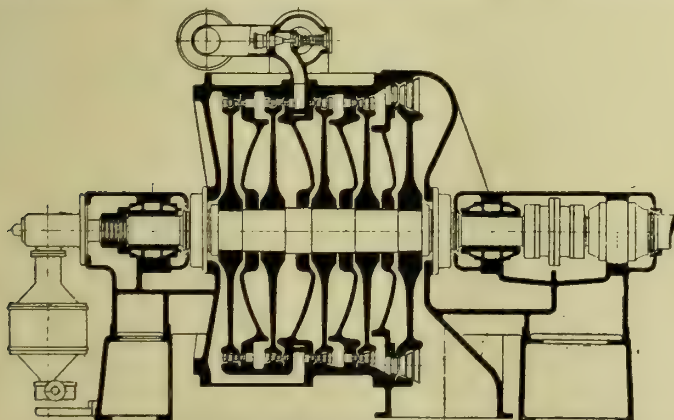


Fig. 14.—Arrangement of Large Curtis Steam Turbine, with steam inlet in middle portion of casing.

to the casing or diaphragms over the openings conveying the steam either from the valve chest or the previous stage. The manufacture of these nozzles is quite a fine art, and considerable experience was necessary to find out the best mixtures and the most satisfactory method of casting. As may be imagined, rather elaborate core boxes have to be employed, and the greatest care has to be exercised in both the pattern shop and foundry to produce the satisfactory results that are obtained. The sides of the nozzles are filed to the correct width, and the division plates being quite smooth, the resulting nozzle is of a highly efficient form. In connection with the buckets and nozzles of the Curtis turbine, it may be pointed out that the running clearances can be very ample without the efficiency suffering in the least. It is usual to provide about $\frac{1}{8}$in. axial clearance, and $\frac{3}{16}$in. radial clearance; it has been found that less clearance does not affect the

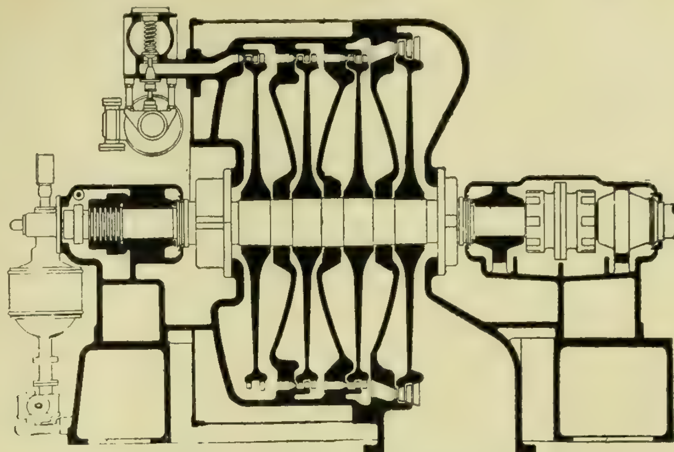


Fig. 15.—Arrangement of Large Curtis Steam Turbine, in which steam flows in one direction from inlet to exhaust.

efficiency, and it is probable that larger clearances could be employed without detriment, but these dimensions have been found sufficient for all practical purposes.

The casing calls for little comment, except for the fact that in all turbines built by the British Thomson-Houston Company, the entire casing, including the ends, is split horizontally, enabling the shaft and wheels to be lifted out for examination or cleaning without disturbing the alignment of the bearings. In some of the larger turbines with many stages and a consequent high first stage pressure, the splitting of the end cover is rendered easier by arranging the steam inlet in the middle portion of the casing, as shown in Fig. 14, the steam passing through some of the stages to one end of the turbine, and returning through passages to the centre again, passes in the reverse direction through the remaining stages to the exhaust. It has, however, been found possible to avoid this complication by making the high-pressure end cover of steel, and in later designs the steam flows in one direction from the inlet to the exhaust, as shown in Fig. 15.

(To be continued.)

Examinations in Science and Technology.—The Board of Education has just issued a revised syllabus (price 3d.) of the examinations in science and technology in the year 1913, as well as for the various scholarships and exhibitions controlled by the Department in these subjects.

British Foundrymen's Association: Scottish Branch. — The Scottish Branch of the British Foundrymen's Association held a meeting on Saturday last at Glasgow, when Mr. George Watt read a paper on "Up-to-date Practice in Ironfounding." In comparing the foundry with the modern engineering shops equipped with their wonderful machines, the lecturer considered it to be less progressive even with the common improvements recently introduced. For the large amount and heavy nature of the castings now in demand for marine engineering work the foundry had to be fitted with sufficient power and electric appliances to deal rapidly with the process of assembling, &c., and the chief considerations for successful work entailed the cutting down of the time of the skilled worker and careful economy in the use of fuel for drying and melting. The principles of dry-sand moulding were fully described, and details given of a modern method of drying moulds by hot air blast. The lecture was illustrated by lantern slides.

ROLLER AND BALL BEARINGS.

THIS subject was dealt with in a lecture delivered by Prof. Goodman, of the Leeds University, at a recent meeting of the Yorkshire Local Section of the Institution of Electrical Engineers. The testing machinery at the University afforded every facility for measuring the end thrust in bearings, which, he said, was an extremely valuable accomplishment. The reason why there was end thrust on a roller bearing was that the roller was not perfectly parallel to the shaft as it rotated, and thus it tended to give in the direction normal to itself. If there was a millionth of an inch of error, the end thrust was just as bad as if there was an error of an eighth of an inch.

Extravagant claims were sometimes made by some makers, and he instanced in particular an American roller bearing guaranteed to be free from end thrust and with no friction, which, on being put into the testing machine, proved to have so much end thrust and friction that the rollers were smashed. The last time he addressed them, he said, he had declared that there was not a single roller bearing on the market worth having, but since then he had found one which, so far as his tests had gone, was entirely satisfactory. They had tried to break it and could not; they had broken the shaft in their efforts, and had had to put in another, but the bearing remained as good as when it was put in. That was a bearing with a short roller. The length of the roller was only equal to the diameter. He had run it at a great overload, much beyond what the maker intended it for, and the results were still satisfactory. Some of these particular roller bearings had failed in actual practice, but he believed that the reason for the failure was that grit had got into them. It was most important to keep grit out of roller and ball bearings. These bearings ought to be as carefully guarded as the springs of a watch. The short roller bearings cost about 25 per cent. more than ball bearings, but they would carry twice the load. What the maximum load was he could not say definitely yet, because he had not yet smashed one of them. So far as his tests had gone, the short roller was an entire success. There was a little end thrust, but it was a negligible quantity.

Referring to ball bearings, he said that in the early days the makers thought that adjustment was necessary, and some of them did not appear to have got over the adjustment fit yet, but, as a matter of fact, there was no necessity whatever for adjustment, and they could not adjust a ball bearing if they wanted to. The early four-point bearing was good for light work, such as bicycles, but beyond that it was never used. Later on thrust bearings came: 45° grooves were made for the balls to race in, and it was very soon found that the grooves were very badly scored, showing that they had been grinding. That type of bearing was wrong, because they could not increase or decrease the load without failure. The three-point bearing failed because of excessive friction and other faults. The two-point bearing was eventually found to be the proper thing, the friction being very much less and the load carried much higher. Then it was found that the hollow race was the right thing instead of the flat race. If there was any doubt about being able to keep the shaft and the bearing in line, the flat race was the better. If they were certain of keeping everything in line, then the hollow race was unquestionably the right thing. A properly-fastened bearing with a hollow ball race would carry about twice the load that one with a flat race would. The best practice was to make the radius of the groove 10 per cent. greater than the radius of the ball. The theory was that the closer they could make this groove fit the ball, the higher was the load that the bearing would carry; but the friction would go up at the same time. The friction was least on a flat surface, but it would only carry half the load, so they had to take into consideration all the circumstances of the case.

The fixing of the sleeve on the shaft, he said, was by far the most important problem connected with ball bearings, and four-fifths of the failures had been due to improper fixing. The man who worked to the nearest sixty-fourth of an inch went hopelessly astray. By far the best thing to do was either to make the shaft deeper and use a nut and fix it solid on the shaft, or have a ring bored out parallel and either forced on by hydraulic pressure or shrunk on. This operation of shrinking must be done very carefully. If sufficient shrinkage was not allowed it would get loose; if too much shrinkage it would jam the bearing. Thousands of ball bearings had been destroyed by getting too much shrinkage, or by forcing them on at too great pressure. The amount of shrinkage should be $\frac{1}{2000}$th part of the diameter, and if this was materially departed from trouble would result. The ring should be heated in a bath of oil up to about 154° Fah., and if the ring could not then be got on to the shaft, it would clearly prove that there was too much shrinkage.

In most cases in which the maker was blamed, the fault was due to people using ball bearings carelessly. The housing of the bearings must be properly arranged. If the outer ring was fitted into a housing which was too small for it, as had frequently been done, even if it was only a thousandth of an inch too small, it would nip in the side when the load came on. If there was noise in the use of ball bearings, it was clear proof that they were doing something wrong. At the University they ran ball bearings under much more severe conditions than any in practice, and got no noise. Step bearings for heavy pressures he described as not a bit of good.

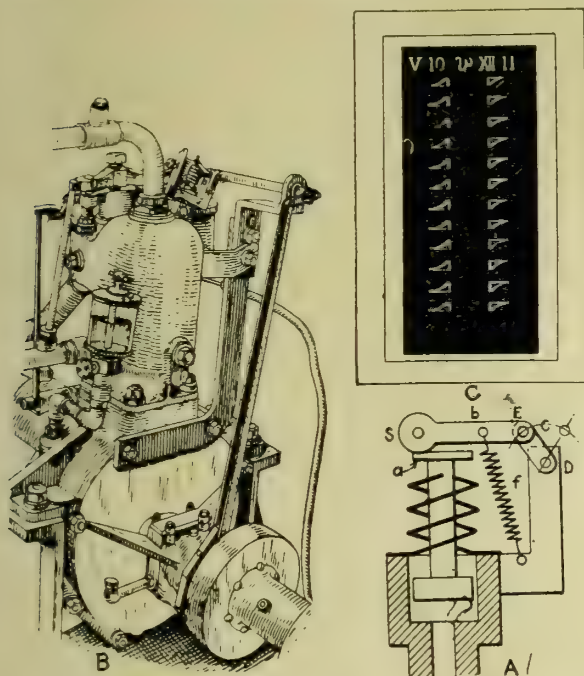
With regard to rings, it was, he said, very important not to depart greatly from the spherical form—the simple form of ring. Emphasizing the need of accuracy of workmanship, the lecturer said if they were wrong to the extent of one-thousandth of an inch—say a thousandth over the inch—they would, approximately, increase the load of the bearing by 100 per cent. Hence there must be accuracy at all costs—wonderful accuracy. Whilst there were some firms in this country who worked to a millionth of an inch, if necessary, there were others who even yet hardly seemed to realise that there was anything less than an eighth of an inch, and the latter were the people who were always complaining of ball bearings. In the University they had carried out thousands of experiments in the attempt to find out the safe load and speed of ball bearings. They had been at it for 10 years, and they had found out how to get it.

If they looked at a ball under the microscope, as soon as ever they exceeded the safe load or speed, they would find it covered with fine specks where crystals had broken away. As soon as these specks appeared they might know to a certainty that the ball was damaged, and would ultimately fail; otherwise, if he had to run ball bearings until they failed, he would be as old as Methuselah before it occurred. The examination of the ball under the microscope had been a complete success. Speed was a most important point. He did not know why speed had anything to do with the matter. The wear of the balls was practically nil under proper conditions, even after very severe running.

Provided that there was absolutely no rust at all, the balls would be better without lubrication, for oil or grease always increased the friction. Lard oil was the best lubricant. Lubrication was needed only for the sake of preventing corrosion, and once in 12 months was probably sufficient. The friction of ball bearings was extremely low; with a properly fastened ball bearing, the starting effort was so small that they did not get a jump, and the friction was entirely independent of the speed. The ball bearing cost three times as much as the ordinary bearing to carry the same load, but the friction was less, no attention was required, and practically no lubrication, and an important point also in the case of a dynamo or motor was that the use of the ball bearing would shorten the shaft and shorten the bed. That was of very great importance, as they saved metal; but what was of importance also with regard to a motor was that the mechanical efficiency of the motor was very considerably higher with a ball bearing than with a plain bearing. So they could supply a smaller machine with ball bearings to give the same horse-power that a much larger machine would give if it had plain bearings. If they asked makers to quote for motors with and without ball bearings, they would find that in many cases the quotations would be lower with ball bearings than with plain bearings. It was true that there were some people who said they would not have ball bearings at any price. They were generally people who had not yet learned that there was anything smaller than one-eighth of an inch—the rough-and-ready people.

INDICATOR FOR SMALL HIGH-SPEED INTERNAL-COMBUSTION ENGINES.

THE "Micro Indicator" shown in the accompanying illustrations has been designed by Mr. O. Mader for use with small high-speed internal-combustion engines, where the ordinary indicator cannot be used. The instrument was recently described in our German contemporary "Der Motorwagen,"



MADER MICRO-INDICATOR: ITS DRIVE AND DIAGRAMS IN NATURAL SIZE.

and we are indebted for the following translation to the Journal of the American Society of Mechanical Engineers.

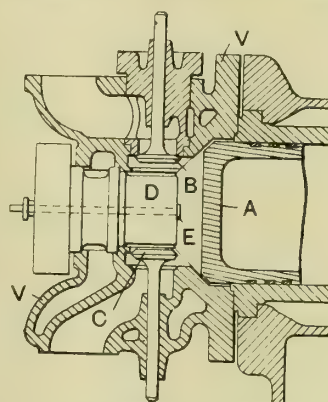
Attempts have been made to use optical indicators for pressure recording, but their disadvantage is that their record must be made photographically, and that leads to the diagram lines being of very uneven distinctness, and being under-exposed in fast-moving machinery, and over-exposed in indicating slow-speed engines. The micro-indicator described, like the early steam indicators, has a short piston stroke and is direct recording. In this case, however, the record is made with a sharp steel point on a soot-blackened glass; the fine lines are then magnified under a microscope, outside of the engine installation proper. Fig. 1A represents the gear which allows the indicator record to be made by minute sidewise motions of the light steel point. The piston rod has at the top a flat plate *a* which is in gliding contact with the end of the rod *b*. The point *s* of the recording style lies exactly in the axis through the centre of the circular end of the rod *b* of which the second end *E* is actuated by the lever *c* swinging about *D*. To keep the rod *b* always in gliding contact with the end of the piston rod, and to avoid lost motion in the gear, the coiled spring *f* is introduced. Since many guide points, even with the best adjustment, are apt to produce excessive friction, the parts in this indicator are all guided at no more than two points; thus, the piston is guided below by the cylinder wall, above by the double-wound spring, the spring, rod, and piston being combined in one piece, and, should another scale be required for the diagrams, must all be changed together; this, however, eliminates all possibilities of their getting loose in operation or being incorrectly put together at the beginning.

An important part of the micro-indicator is the diagram holder, a U-shaped frame rotatable about a fixed axis; the soot-blackened glass is slipped in from above and held fast by a spring. The simplest drive, with as few joints as possible, is used, *e.g.*, a rocking drive (Fig. 1B). To avoid large errors in the diagrams, the setting of the drive must be carefully made, not only as regards dead centres, but also with respect to the average piston position at which the recording style is instantaneously at rest previous to changing its direction of motion. The diagrams are magnified by an ordinary microscope with a 1:40 rate of magnification, which is sufficient for an estimate of the diagram by inspection. If measurements are to be made, the diagrams are magnified either photographically, or drawn to a larger scale by means of a special reflecting and magnifying device. The indicator may be used for the determination of the indicated horse-power of a high-speed internal-combustion engine (600 to 3,000 revs. per minute); the glass on which the records are made may be cleaned, covered by a new layer of soot or lampblack, and used over and over again.

CYLINDER HEAD FOR INTERNAL-COMBUSTION ENGINES.

IN internal-combustion engines, particularly Diesel engines, which work with high compression, the compression space must be small. If the exhaust and admission valves are arranged substantially co-axially with their axes at right angles to the cylinder axis, which is usual in horizontal engines, the necessary small compression space may be procured by placing the valves a comparatively short distance apart, whereby the transition space between the cylinder and the compression space must be sharply coned, and in order that the compression space may be small the piston must be correspondingly conical in shape. Owing to this, the compression space is of irregular shape, affording a large surface for the conduction of heat as compared with the compression space in engines having their valves in the cylinder cover and therefore a compression space of discoid shape.

In the design illustrated, which has been patented by Messrs. Körting Bros., of Linden, near Hanover, it is possible in an engine wherein the valves are set widely apart and are arranged in the cylinder cover substantially co-axially and with their axes at right angles to the cylinder axis, to have the satisfactory discoid-shaped compression space characteristic of the vertical type of engine. For this purpose the space intermediate of and co-axial with the valves is filled by a body separate from the cylinder and cylinder cover. This separate body extends comparatively close to the end of the piston when the latter is at the end of its inward stroke, and contains the injection nozzle. This body is removably supported by the cylinder cover in a similar manner to that of the hollow blocks used in some known types of internal-combustion engines to form combustion chambers. Referring to the illustration, which is an axial section through the end and cover of the cylinder of a horizontal internal-combustion engine, V is the cylinder head, A is the working piston, B the admission valve, C the exhaust valve, D is the body which fills the space between the valves, and is formed as a cover which may be withdrawn. This body D leaves only sufficient play for the valves C and B to permit them to open widely enough for the exhaust and admission respectively. E is the injection nozzle. The exhaust valve C can be easily withdrawn after the admission valve B and the body D have been removed. Through the opening in which D is inserted, the compression space may be inspected and easily cleaned.



CYLINDER HEAD FOR INTERNAL-COMBUSTION ENGINES.

The New British Airship.—The Parseval airship for the British Admiralty, now under construction in Germany, will, according to the "Berliner Tageblatt," be completed by next spring. The new dirigible will have a capacity of about 10,000 cubic metres and a length of 292ft. Its greatest diameter will be 49ft. The car will be about 39ft. long, 5ft. 2½in. wide, and contain room for 15 to 20 persons. Two Maybach engines of 150 h.p. each will drive two steel propellers and ensure a speed of about 40½ miles per hour. The duration of the voyage is to be from 20 to 25 hours, and the maximum height of ascent of the dirigible is estimated at 6,500ft. The manning of the vessel will require five or six persons. A similar dirigible has been ordered by the Russian Government, which already has two Parseval airships.

STAFF OFFICERS IN INDUSTRIAL WORKS: THEIR SCIENTIFIC AND PRACTICAL TRAINING AND DUTIES.*

By Sir A. Trevor Dawson, R.N., M.Inst.C.E.

My first duty is to thank the members of the institution for the honour they have conferred upon me in electing me to the office of president for this year. It is an honour which I value highly, coming as it does from engineers who have succeeded in establishing an institution which has all the vitality of youth. The hope of the future lies with the youth of to-day; a large proportion of your members are young men, and I am always proud to be associated with young men. I am also honoured by association with the illustrious company of my predecessors. It is widely recognised that no institution connected with engineering includes in its list of past-presidents a greater proportion of eminent engineers and distinguished representatives of every department of applied science than is the case with our institution. Most of my predecessors were chosen by you because they were illustrious, but some, no doubt, because you desired to stimulate them to make the most of their professional life. As regards myself, I frankly admit that my election by you as your president is one of the most stimulating and encouraging influences which have come to me in my work.

The intimation that the presidential address was due on a particular evening had a benignly chastening effect. There was first the difficulty of choosing a subject suitable for the occasion. Every autumn brings a flood of presidential oratory, growing in volume year by year, and encompassing the whole field of available subjects. As a consequence, it becomes increasingly hard to select a topic for consideration in keeping with and worthy of the record of this institution. It is harder still to say anything new upon any phase of engineering which may conveniently be discussed from the presidential chair. Reflecting upon this, I remembered the suggestion of a pastmaster in presidential oratory to the effect that a president should confine himself to a straight talk from his own inner consciousness on a line of reasoning along which his audience may accompany him towards some Mount Pisgah of inspiring prospect. This seemed to me idealistic. An enquiry for something more simple and practicable brought the response that it would be acceptable to you if I spoke of the qualifications desirable in those seeking appointment as staff officers in industrial works. This may seem somewhat personal, but obviously any fairly inclusive treatment of such a theme must include general reflections upon the importance of associating scientific knowledge with practical experience in the case of staff officers.

The demand now is for well-trained young men having experience of materials, mechanical methods, and men. These three forms of experience differ widely. It may be said, too, that the personal characteristics requisite for acquiring and assimilating the experience differ widely. The sources of these types of experience also differ. The fields in which each is to be applied differ. Nor is it possible for one to attain efficiency in the highest degree in all three departments, and there are relatively few appointments in the industrial world where all three are essential in the superlative degree. But this is only one more instance where it is desirable to have intimate knowledge of one, and an intelligent general acquaintance with the other subjects. The personal characteristics of the student and the goal he was to reach—the appointment on the staff aimed at—must be considered in determining in which direction there shall be specialisation. For the moment it is enough to establish that experience is a dominant consideration. This cannot be too forcibly emphasized, for young men are at times prone to seek advancement without carefully considering whether that which looks like advancement will conduce to the winning of the experience so invaluable in future work.

One of the strongest characteristics of youth is impatience, indicated in the desire to advance rapidly to high-salary posts. This in itself is quite a hopeful trait, in so far as the striving for personal advancement may in its cumulative form tend to advancement in engineering practice. But the course which leads most rapidly to an advance in pay is not necessarily so advantageous to the young man, particularly if it involves, as it usually does, a loss of opportunities for gaining fuller experience. This gain in experience will in time yield a much larger profit than the interest or dividend on savings from salary. This dictum may seem hard when the cost of living is considered; its hardness is a matter for State consideration, as I hope presently to show: but its truth cannot be disputed. A youth seeking knowledge and experience does not wish to continue in one department or at one job after he has become proficient. On the other hand, he only begins to earn his wage, plus the necessary profit to industry, when he does become proficient. Unfortunately, this proficiency tempts the youth to remain too long at one job, as he can thus net for the time being a greater pecuniary gain, but this continuance at one job tends to limit his experience. A change to another department or job usually means less pay, owing to the youth's lack of proficiency in the novel class of work, but to him this loss is more than compensated by a gain in experience. He is a wise youth who, when he can afford it, accepts experience as part of his remuneration.

An ordinary apprenticeship under the circumscribing conditions inevitable in the commercial conduct of a factory can be sandwiched with some measure of theoretical training. As a result, the standard of efficiency of workmanship is improved. Facilities are afforded by many firms to enable apprentices to attend science classes in the evening, and encouragement is given by increased wages according to the standard attained in class-work. This procedure, too, opens the way for the intelligent and industrious youth to advance beyond the ranks of the ordinary workmen. To such diligent apprentices every help should be given. But I am not concerned now with workmen, or even foremen, who rise to such posts by study and application during apprenticeship and subsequent to that period. There is a national need for much more highly trained engineers—men combining scientific and practical knowledge, and, as I have said, having experience of materials, mechanical methods, and men, to serve on the staff of works. The existence of this need I wish to enforce most strongly; later I shall try to indicate a means for meeting it.

Engineering is a profession which is constantly extending its boundaries. Mechanism is now applied more extensively and for a greater variety of purposes than was thought of 20 or 30 years ago. New problems are involved in most of the new applications. The demand for higher efficiency has increased, owing to intensified competition, and at the same time difficulties of excelling after each new step forward are intensified. It was easy 20 years ago, for instance, to reduce the coal consumption of the steam engine from 2lbs. per effective horse-power per hour; to-day it is difficult to take even a fraction from the 1¼lbs. of coal now required, and yet the demand is as insistent. Thirty years ago the steel used generally was almost wholly ordinary carbon steel; alloys were practically neglected. But since then such progress has been made with high tension alloys that it has become most difficult to improve upon the results now realised. Yet the aeroplane and other new products must have material to withstand still higher stress. There is need, too, for a metal which can be subjected to very high temperatures; it is recognised that the advent of an oil turbine—the most desired of all prime movers—is delayed largely by the absence of a metal for the blades which will stand the temperature of the gas impinging on them. These typical examples prove the need for wider technical training and sympathies. Nor can the engineer of to-day be content to accept the same line of action as his predecessor of another generation. In view of his higher and broader and deeper knowledge and of his more varied experience, more decided departures from the practice of the past may be anticipated.

Metallurgy demands first consideration. A knowledge of the properties and the effect of treatment of metals is a necessity in all British factories. The day is long passed when the list of materials included only iron, steel, cast iron, and brass. If we take the modern warship, we find that rarely are any of these metals used in their simple state; they are alloyed with others, in many cases with the rarer metals. Take, for instance, the high-tension brass now used. By alloying small percentages of iron, manganese, &c., with ordinary brass, the

* Presidential address delivered before The Junior Institution of Engineers, December 11th, 1912.

tensile strength is increased from 12 to 14 up to 30 or even 40 tons per square inch in a casting; and such material, too, can be readily rolled or forged at a dull red heat. Every candidate for a staff appointment should know something of such alloys, because while the laboratory staff may formulate instructions as to constituents, heat treatment, and machining generally, it is necessary that there should be intelligent control in the foundry and workshop. He must have a sufficient knowledge of chemistry and metallurgy, of the chemical actions which take place in the furnace, and of the shrinkage which may be expected during cooling in order to realise the limitations and difficulties for which provision is necessary.

Even simple steel—the most used of all metals—is difficult to define comprehensively, since it is so complex. For this reason there is need for a clear understanding of the chemical composition and special treatment required to ensure that each particular quality shall possess the properties desired for the duty to be imposed upon it. Many breakdowns are due to a lack of appreciation of the possible varieties and phases of this complex metal. The behaviour of steel, indeed, is often mysterious, and the causes of failure cannot always be discovered, because the investigator is not in possession of the facts as to the manufacture and treatment of the material. It is not enough to say vaguely that "steel" shall be used for a given product where high stresses are to be met; much more has to be specified. How different, for instance, are the properties of mild steel and a piece of modern high-speed tool steel, and yet both are steel to the ordinary mind. Who could have foreseen the possibility of a tool retaining its cutting edge at a red heat and ripping off material from other varieties of steel in the form of turnings that become blue from the heat generated by the friction of the cutting tool? Again, by the same association of chemistry and metallurgy there has been evolved the nickel steels, which are so advantageous in affording an increased strength from a given sectional area. Questions as to durability and resistance to corrosion are also being solved through the study of chemical composition and micro-structure, and by treatment of the metal after its production.

The materials used in manufactures greatly affect the design, and therefore the efficiency, of the production. This is of greater importance even than economy in output, particularly where weight must be minimised and strength increased. These factors enter largely into the consideration of competitive proposals, notably in all implements of war and in high-speed merchant ships. Durability, too, is an essential condition in all mechanical appliances. Indeed, it may be taken that for all contracts for which there is international competition, a fuller recognition of the importance of providing the most suitable material is absolutely essential.

As with materials, so is it with power production, whether for transport, factory driving, or other purpose; scientific problems call for superior knowledge. Economy has become of increasing significance. A reduction in weight confers great advantage mechanically and commercially. The candidate for a staff appointment must have an adequate knowledge of thermo-dynamics. It is incumbent upon the engineer to see that the greatest percentage of the thermal energy stored in his fuel shall be converted into mechanical work as far as commercially practicable. This involves examination of the composition and calorific value of fuels and of the conditions necessary for complete and economical combustion, which in themselves abolish the smoke nuisance. Much, it is true, has been done in this direction, the stimulus coming largely from the navy and in some part also from the high-speed merchant service. The choice of fuel is, in some cases, a commercial question, dominated by the location of supplies and by its price; but the engineer must be prepared with the most effective mechanical appliances for using whatever fuel is fixed upon. There is no need to attempt to differentiate the designs of boilers to suit various fuels or to point to the importance of such knowledge as will enable the engineer to determine the effects of salts found in feed water from different localities upon the tube and other heating surface, or to prevent scaling, pitting, and corrosion. Nor is it necessary to enlarge upon the importance of dry steam or of superheating the steam.

It is appropriate, however, that reference should be made to the significance of recent developments in the use of oil fuel. Where weight has to be minimised the higher calorific value of oil makes it preferable to coal, and now that all our warships use liquid fuel to generate steam in boilers, it seems surprising that the change has been so long delayed. The wonderful success of the steam turbine invented by Sir Charles Parsons, one of the most distinguished past-presidents of our institution, made the change of fuel imperative, first because the turbine excelled the boiler in endurance at full speed and because it could at any time take a great overload. The loading of oil into the storage spaces in a ship, and its transfer to the furnace are enormously simpler than is the handling of coal. As regards weight, the saving with oil-fired boilers and turbines against coal-fired boilers and reciprocating engines is 20 per cent., the fuel supply included in the weights in both cases being for the same radius of action, and all other conditions being analogous. Great credit is due for the reduction in weight in torpedo-boat destroyer machinery to 35lbs. per shaft horse-power, excluding fuel, and for the reduction of the fuel consumption to about 1lb. of oil per shaft horse-power at full power.

Without attempting to disparage the possibility of further progress along the same lines, the engineer must be prepared for departures from these, and, indeed, from all traditional designs. He must not be content to accept that which exists because it seems to have done so well; the creative mind, as distinct from that of the copyist, will seek for new lines of advancement while accepting approved mechanical principles. For instance, he will only act logically in urging the use of fuel oil in its most direct form. Why use a boiler to convert the heat of the fuel into steam for doing work in the cylinder when the oil can itself work directly the piston in the cylinder? It is true there are difficulties, and that these increase in degree with the size of the cylinder. Until the demand for machinery which could propel submersible warships, the application for marine propulsion of this principle of combustion of oil within an engine cylinder was treated in a somewhat dilettante manner. The experience thus gained justifies the view that all difficulties can and will be overcome. They are mentioned here only because they throw further light upon the extent and varied character of the technical experience in mechanical machinery required in modern engineering. There is the choice of oils, the proportion of air necessary for efficient combustion, the effective scavenging of the cylinders, the properties of the metals used and subjected to rapid alterations of extreme temperatures, and the nature of the material for working parts in order to reduce weight without sacrificing strength or durability. These are all in addition to the usual requirements of simplicity of mechanical details and reliability of control and working conditions.

I admit that there are difficulties which seem with our present knowledge inherent to the internal-combustion engine. That, however, is a stimulating reflection for the young engineer who seeks for more worlds to conquer. The power which a cylinder can safely develop is at present not so great as that possible in the steam engine, because the temperature is so much higher with the internal-combustion engine; but this may be overcome with superior materials. This raises the question of the two- as against the four-stroke cycle, and of double in preference to single acting. The oil engine of the future must necessarily be of the double-acting, two-cycle type, if the maximum of power is to be got from each cylinder, and here is afforded a great field for ingenuity and patience in experiments. Again, there is no reasonable objection to multiple cylinders. It is true they increase the number of working parts, but on the other hand the proportion of power unavailable through the breakdown of a cylinder or its working parts is diminished. The same objection to multiplicity of cylinders was raised when two engines were adopted for twin-screw ships in order to meet the need which arose for more steam cylinders and shafts for higher powers. It may be noted, too, that among the recently-built Atlantic high-speed passenger liners is one with 16 steam cylinders in the propelling machinery, eight for each propeller shaft.

We are told that a return to reciprocating machinery is a retrograde move, and that the ship will vibrate more than with turbines. The rotary system has much to commend it, and it may be that the extended use of the internal-com-

bustion system in reciprocating engines will help towards its application in some form of rotary or turbine engine. Experience with the heavy oil marine engine has provided most satisfactory results, and does not bear out prognostications as to undue vibration. The possibilities in the direction of reduced weight for machinery and fuel certainly justify the desire for fuller experience. The saving with an oil engine installation in a large ship is equal to about 20 per cent. when comparison is made with steam machinery, all other conditions being analogous, and fuel included in both cases for a radius of action equal to that aimed at, for instance, in British battleships. The superficial space required is about 23 per cent. less. In addition to the advantage in respect of supply and storage obtained with the use of oil in boilers, there is further undoubted gain due to the absence of funnels, the mast serving for the exhaust. This enables the guns in warships to be placed more effectively.

Nor is the field for utilising scientific knowledge and practical experience confined to the prime mover—promising as is that field. In all departments of applied mechanics there is need for the creative mind, for inventive and adaptive genius. This is particularly the case with manufacturing appliances. To combat competition, economy in manufacture is only less important than the suitability of the design and the efficiency in operation of the product. Some may claim that cost is of equal importance; that is true in some cases, but where there is scope for originality in conception, for ensuring reliability and for improvement in working results there is still the probability of these qualities, along with price, appealing to the buyer as elements in the estimation of true value. Our industrial supremacy depends on our progress along these lines as much, if not more, than in the matter of cost, and it is to these considerations that attention must be directed by the engineer who is jealous of the part Britain plays in advancing applied science.

But these, nevertheless, ought to go hand in hand with economy in production. This is influenced by machine tools, organisation, and workmen. A staff officer accordingly ought to have intimate knowledge of all three, and the mental capacity to analyse the operation of all three with a view to continuous improvement. It is true that the design of machine tools has become one of the most specialised branches of our profession, and that good results have accrued. These need not be elaborated. But there still remains the need for discrimination in the purchase of new tools in order to ensure that the machine is not only well designed generally, but absolutely the most suitable for the work to be done. It happens, too, at times that results may be greatly improved by some addition, modification, or adaptation. Thus there is the user's point of view in machine-tool work as well as the maker's, and only experience in the use of tools can ensure the highest workshop economy.

Organisation is a large subject, involving commercial as well as technical considerations. Into the former it is not desirable to enter. The engineer, as such, has no concern with the effect of trade-union conditions of employment on mechanical appliances, and this need not be considered here further than to express the hope that the difficulties of these conditions will never arrest the work of the creative and adaptive faculty of the engineer in the direction of extending and quickening mechanical operations in the factory. The work of organisation embraces the continuously extending utilisation of mechanical in preference to manual operations. This calls for a record of costs, so reliable and comprehensive as to enable comparisons to be made between the two systems so that it may be easy to decide whether interest on capital will be earned by new machines.

Now we come to the most difficult of all problems which beset the young engineer—the management of men. There are certain occupations in which a man can design and complete his work himself. The painter, the littérateur, the musician, can labour in solitude, and their products are the fruit of their own brains. But with the staff officer the case is quite different. He has largely to see through other persons' eyes, to hear through their ears, and to act through their hands. The day is not long enough for him to take personal cognisance of everything for which he is responsible. He must act to a great extent through subordinates. When they serve him well he gets the credit, and when they serve him ill he bears the blame. It is therefore of immense importance to him, and the firm he represents, that he should, in the first place, select his assistants with skill; and, in the second, imbue them with a spirit of loyalty. Nothing conduces more to good service than the knowledge among the rank and file that the chief can take any job out of their hands and do it as well as or better than themselves. In early years this state of affairs is quite possible, but later, as the province under a man's control widens, he can no longer be an adept in every department. Then his method of influencing those below him must be moral and intellectual rather than technical. He must be a student of character, able to discern both the strong and the weak parts of his assistants. He must encourage the diffident, stimulate the lethargic, and repress the erratic. There are no books that explain how this is to be done, and no professors who lecture upon the art. It can only be acquired by constant effort, and the effort must be begun in early years, long before the engineer has much opportunity of putting the lessons into practice. A review of the careers of the great men of the world shows that they were always surrounded by capable assistants of their own choosing, and he who hopes to rise to a post of great responsibility must practise the study of character with assiduity while able to be on familiar terms with his fellows. As one grows older, a veil gathers between one and one's acquaintances. There is no longer the easy familiarity of earlier years. It is not possible to gaze into the depths of their dispositions with the ease of former days; opportunities of studying human nature are gradually curtailed. The foundations of the knowledge of character must be laid early in life.

Difficulties beset the direction of men who have reached the period of life when it is not easy to effect any great change in them. Workmen are brought up in a narrow school, and their limitations must not be forgotten. Success will be attained by the staff officer adapting himself to the workman's standpoint rather than by seeking to transform him. The difficulties which are experienced by young engineers are often intensified owing to impatience, lack of experience, a failure to recognise idiosyncrasies and a hesitancy to discover latent worth not measurable by some preconceived but incomplete standard. There is no better artisan than the British working man. He is actuated by the motive to maintain the credit of his craft. He is right in seeking the best market conditions; but he may not always adopt the most reasonable line of advocacy or the most thoughtful advocates. It is a function of management, however, to encourage the higher motives, to adopt the most conciliatory attitude, and to encourage a reflecting and broad-minded line of policy. Workshop experience is thus highly essential in a staff officer —if the best is to be got from machine tools, organisation, and the management of men; on the other hand, technical knowledge is indispensable to the evolution of design and to the choice between alternatives in design, in materials, and in mechanical methods.

Is all this a gospel of perfection? Is it not obvious that if we are to maintain our position as a great industrial nation there must be advance in the science and practice of our profession? The payment of higher wages, which all desire—employer and worker alike—can avail nothing if the cost of living is increased by reason of the cost of production and distribution going up correspondingly. The finished product —the merit of its design, its durability, its low first cost, and its economy in operation—is our primary consideration. By maintaining these qualities the remuneration of the worker and capitalist can be ensured without the selling price being raised, and therefore without its user being penalised, and without, to this extent, the cost of living being augmented. That is the crux of the problem pressing equally on the engineer, the industrial economist, and the labour leader.

Our concern, however, is purely with the engineer's part, and it will be recognised that it offers a task worthy of the highest ambition. The aim may be impossible of achievement in its entirety by any one engineer, however highly and widely trained. Ideals would cease to be ideals if they could be realised. But an ideal may be to anyone what the pole star has been to the navigator. By it many ships have been guided to various ports. Any single engineer cannot acquire the full sum of the experience required in an engineering factory; but he should gain as much as he can in the most receptive years of his life.

It cannot be too often enforced that, with the increasing intensity of international competition, there is need for the utilisation in industry of the best mental capacity the nation possesses. It is recognised on all hands that the education of the people is a national duty. We have long since passed the stage when only the primary rudiments of education are provided by the State. To-day we have to wonder when and where will the State provision of educational facilities end. Research scholarships for science students were established by the 1851 Exhibition Commissioners; but the students thus trained usually pass into the teaching profession. It is no disparagement to this, one of the most valuable branches of the national service, to say that industry, as well as education, merits a share of the fruits of this expenditure, as the endowment was the result of a great industrial exhibition. This fact is now being recognised; but more is necessary.

Other States adopt methods for assisting industry by helping to train men capable to take staff appointments in industrial factories. Under present conditions, and especially in view of the high and varied qualifications necessary for such staff appointments, the training must be prolonged. In order, too, that the highest results in scientific knowledge and practical experience may be realised, a considerable expenditure is involved, and there is, moreover, little chance of wages being earned during the time. Only those liberally endowed can support themselves throughout the process. Such apprentices as can afford to pay premiums for the practical part of the training, as well as the fees at college, are not always acceptable in works, because it has been found that many of those so endowed, having their future secure, lack the incentive to take full advantage of their opportunities, and have, therefore, a retarding influence on other youths in the factory. On the other hand, a shortage in financial resources should not block the career of the young man of requisite calibre and character, for whom only the opportunity is needed to develop his possibilities and direct them into the most appropriate course. In London and in rural districts, where there are few engineering factories, such youths have difficulty in finding the opportunity which would enable them to become recruits for the great mechanical industries.

It is true that our great technical institutions in the Metropolis and provincial cities are not excelled in any country in the world, and it is creditable also that our great city companies and many private endowments have assisted many less favoured in the "world's goods" to prosecute their engineering studies at such institutions. Yet the results have proved unsatisfactory, alike from the point of view of the student and the nation. The absence of practical training, of early contact with the workshop, deprives these students in most cases of an indispensable part of their preparation for future industrial work, and interferes with their finding a suitable vocation after their college course has been completed. Experience has established beyond a doubt that if a youth does not enter the shops long before he is 21 or 22 years of age, when the technical college course usually terminates, his chances of becoming a thoroughly satisfactory staff officer are greatly diminished. His course at college has not been stimulated by that matured conception of the need of knowledge on certain definite lines which contact with practical work creates. At 22 years of age he is less tolerant of the rough and tumble life of the workshop; his mind is less plastic, and he has already formulated notions as to the character of the workmen which makes it difficult for him to realise that the craftsman has much to teach him. Moreover, he does not get into the same sympathetic relationship with the workmen as he would possibly have done at an earlier age, and thus in negotiations with workmen later on, he is placed at a disadvantage owing to lack of experience of the idiosyncrasies of men and of their standpoint in all questions—mechanical, economical, and social; in other words, the college "standard" is between him and a recognition of the true worth of the worker.

The contact with practical work and all it involves alike in machine tool design and working establishment organisation and the qualities of workmen is the necessary preliminary to the college course. It may be pursued for three continuous years or be sandwiched in thick slices with the college course, but there is a preference for the former when associated with evening class work along with that of the ordinary apprentice. Beyond this, there is, when the college course is concluded, an undertaking on the part of the firm to take such apprentice student direct from the college into the works for a further period of high-class training at a good wage. Thus there is secured for the student a stimulus during his college course due to his past workshop experience and the surety of a position after that course is concluded.

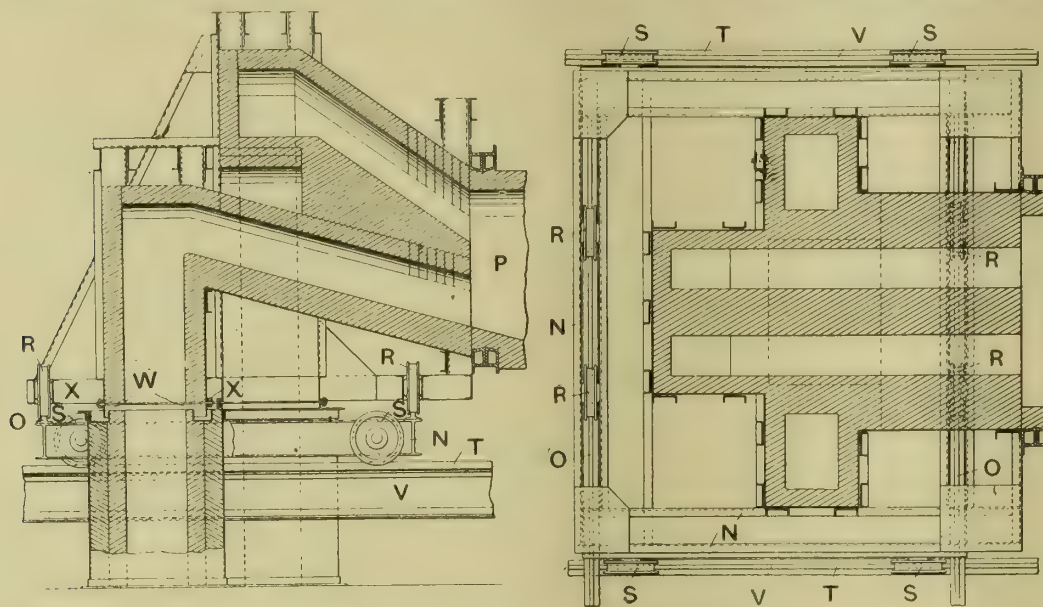
There may still be, through lack of means, the difficulty of pursuing this course from the beginning of workshop experience, through college and during the subsequent higher educational course in the works. Yet these are essential if we are to have satisfactory staff officers—young men of creative and adaptive genius, capable to maintain the high efficiency of the nation in applied science. The field of selecting such youths, too, should be widened so that the best brains of London, and of every rural district as well as provincial engineering towns, can be secured. As has already been said, if the experience acquired is to be on the broadest basis, the youth cannot be expected to produce work which, in the earlier stages, will be thoroughly remunerative for his employer. His wages can only be a minimum, paid really to ensure equality with others who work with him, in order to ensure a maintenance of discipline. Even then some disadvantage must accrue to the employer who grants special facilities for the acquisition of experience on the part of the apprentice. For a youth who has to pay for his living with little or no parental help, there is a severe handicap.

Is it too much to expect that, as there is great national need, the State should extend its educational system so as to enable the best of our youths to enter upon a combined practical and theoretical training for the greatest of our manufacturing industries, without requiring great sacrifices on the part of parents who may be unable to support their sons throughout the prolonged period of training? Such a scheme need not be confined to engineering, although it is with engineering that we are here concerned. Foreign Governments nurture their industries in many ways: they provide means for the constant supply of staff officers for factories, and if we are to continue pioneers in inventive work, similar methods of encouraging talent must be adopted. There are details to be considered, such as the choice of the State industrial apprentices, the provision of methods of testing their earnestness, application, and proficiency from time to time during the course, so that any retrogression may be visited by a withdrawal of the State's support, and the insurance that State industrial apprentices will continue to serve the Empire only after their training had been completed. But all of these details can easily be arranged once we accept the principle of selecting and nurturing the most promising mental talent of the nation, independently of the stratum of society in which it is discovered.

The duty of fostering mechanical science is one which will yield the highest reward to the nation, and should commend itself apart altogether from its social considerations. We live in an age in which mechanical science is pre-eminent. It affects the national activities in every direction; national prosperity and national security are dependent on our supremacy in engineering in every department of practice. Every phase of life is affected by the work of the engineer. The manufacture of all the necessities and most of the luxuries of life, the transport of products, even our pleasures, come within the scope of the mechanical arts. The adequate employment of all at a remunerative wage and the reduction of the cost of living are tasks set to members of our profession. Our most clamant national need, therefore, is for high-grade intellect to create new appliances, to improve old apparatus in manufacture, to perfect design alike with regard to its applicability to work, to durability and to economy in operation, so that we may hold our own with all competitors. On this and on the efficient manufacturing process, and incidentally on the amity between capital and labour, our national success is dependent, and true statesmanship can do much in assisting towards the discovery and fostering of the brain power and character fit to carry into effect the highest ideals of a great manufacturing nation.

PORT BLOCKS FOR METAL MIXERS AND OPEN-HEARTH FURNACES.

In metal mixers and open-hearth furnaces having removable port blocks or burners, it has been proposed to mount the latter on wheels which run on rails parallel with the central line of the mixer or furnace, so that they can be removed in an endways direction, that is, parallel with the central line of the mixer or furnace. Instead of this parallel movement it has been suggested that the port blocks or burners may be arranged to be pulled sideways, that is, at right angles to the central line of the mixer or furnace, the dippers being either raised out of the seal or detached from the port block or burner to permit of either of the aforesaid movements. To enable the port block or burner to be removed either sideways or endways, Mr. B. W. Head, M.A., A.M.Inst.C.E., 47, Victoria Street, Westminster, S.W., has designed and patented the arrangement illustrated. The port block or burner is mounted upon an under-carriage N which is provided with rails O in lines at right angles to the central line of the mixer or furnace (a part of the main body of which is indicated at P), and the port block or burner has wheels R which will run upon the rails O carried upon the under-carriage N. At the lower side of the under-carriage are wheels S for running parallel with the central line of the furnace. Rails are shown at T on the supports V for these wheels S to run on. When it is desired to push the port block or burner up against the mixer or furnace, or to withdraw it, the under-carriage N is run on its wheels S. When it is desired to draw the port block or burner sideways for repairs or other purpose, it is run on its wheels R upon the rails O on the under-carriage N, and a track is provided upon the platform to coincide with the rails O on the under-carriage N at some convenient point in the motion of the carriage. The dippers of the seals (one of which is seen at W) are arranged so as to be easily detachable from the port block or burner. This is accomplished by making them so that they surround each uptake separately and are secured by bolts X, easily accessible for detachment or attachment. The combination of the under-carriage N with the port block or burner can be used whether seals and dippers are used or not.



PORT BLOCKS FOR METAL MIXERS AND OPEN-HEARTH FURNACES.

RAIL CORRUGATION.

The subject of "Rail Corrugation" was dealt with by Mr. H. T. Wakelam, M.Inst.C.E., in a paper recently read before the Institution of Municipal and County Engineers. The paper was based on the returns received in answer to the questions sent out by the Tramways Committee of the Institution to engineers in charge of tramway systems in the United Kingdom. He said that from information contained in the answers received it might be argued that the trouble was chiefly set up by combined influences, such as (*a*) the constant oscillatory motion of the car wheels on the rail surface, due (1) to high speeds, (2) to bogie cars, (3) to short wheel-bases, and (4) to heavy car platforms; (*b*) the rigid bed, which, for stability of the road surface, must necessarily be laid down; and (*c*) curvature of track. In this last connection it was clear that the curves, generally, of tramways, steam railways, and electric railways were affected by corrugation to a greater extent than straight tracks.

Constant and rapid braking, under the fast traffic of to-day, no doubt caused varying and irregular impacts between the wheel tyres and the rails. These varying impacts, with the influences already referred to, might have a considerable bearing on the question, especially when "wheel flats" were correlatively considered. It might be that vibration combined with the influences already mentioned might also have some bearing on the question. To prove the length of vibratory waves along tramway rails produced by varying speeds of rolling stock the writer made experiments on the Middlesex County system and found that in connection with a car travelling at a speed of 12 miles an hour the wave was noticeable on the railhead at a distance of 240 yards from the car; that at a distance of 160 yards vibration was general; that at a distance of 70 yards vibration was distinctly accentuated as the car passed over each joint, and that vibration was not so pronounced on the curves as on the straight tracks. Thicker rail webs than those commonly used on tramways would, no doubt, obviate vibration to some extent, and in this connection lengths of track so constructed might well be laid for the purpose of experiments with both high and low carbon rails.

Very little corrugation appeared to be noticed where the car traffic was of a light nature, and the trouble appeared to increase in ratio to the traffic. Tracks used by bogie cars were more corrugated than those confined to cars with fixed frames. This might be due to the oscillation caused by the small wheels of the former. Tramway rails of the same section and make, subjected to the same tests, corrugated to varying degrees and also varied considerably under actual wear. Corrugations affected tramway rails laid on concrete beds of almost any strength or thickness. Corrugation was also experienced where the rails were laid on longitudinal wood sleepers embedded in concrete. It was stated at the Paris Congress that from actual tests soft rails corrugated less than hard rails. Hard rails were, however, universally accepted as being the most economical for general wear.

In reply to questions sent out by the Institution it was stated (1) that in the town of Perth the trouble affected both rails, but on one particular length of track only; and (2) that at Sunderland corrugations appeared and disappeared on tracks where speeds were fairly high, and that, after disappearing for a time, they were again showing. In the latter connection it would be of interest to know whether or not there had been alterations or changed conditions in the tracks or rolling stock or in regard to the speeds at which the cars travelled.

Rail corrugation did not confine itself to tramways only, but was also met with very extensively on both ordinary steam and electric railways. The fact that it occurred on lines that were used by steam-driven trains only altogether upset the theory of those who stated that corrugations were set up by electrolytic action. In regard to tracks used by electrically-driven trains, where the usual "side-supported" construction had been adopted, corrugations were constantly met with. But an important case was that of an electric "tube" railway, in which the track, which had been in use about six years, was constructed with a centrally-supported track. Up to the present there was no sign of corrugation on either the curves or

other parts of the system. In contradistinction there was an electric railway, under the same control, which was constructed on the ordinary steam track principle. On this corrugations had proved most troublesome—especially on the curves—although the rolling stock employed was common to the two systems and the rails used were identical, viz., Sandberg silicon.

From these facts, notwithstanding anything previously referred to in this paper, it might be well assumed that the principal cause of the trouble arose from, or was connected with, track construction. An experiment recently carried out on a curve of ten chains radius (on an ordinary ballasted railway track) afforded ground for reflection. Shortly after the curve was laid corrugations or batterings were very pronounced, and careful measurements were made of their positions, depths, and pitches. After a time the curve was taken up and relaid with new rails of an exactly similar pattern and make to those first adopted. After some wear batterings or corrugations appeared again at the same identical spots and to the same depths and pitches.

The author endeavoured to find out in connection with both steam and electric railways: (*a*) Whether the pitch of the corrugations (or batterings) varied with the speed of the trains; (*b*) whether the corrugations varied in their pitch in ratio to the speeds; and (*c*) whether corrugations (or batterings) were more frequent on curves than otherwise. The information received on points (*a*) and (*b*) was to the effect that the pitch did vary under different speeds, but no actual results in ratio were forthcoming. In regard to point (*c*), corrugations (or batterings) were undoubtedly more frequent on curves than otherwise.

The author concluded that corrugation must form some inherent attachment to all track constructions which did not possess more or less resilient beds, and it remained for some ingenious person to design a track for electric traction on roads which would give both resiliency and stability for tramway traffic, with reasonable maintenance charges, and, at the same time, provide a surface which would satisfactorily sustain, for a reasonable period, the ordinary road traffic. He considered that the replies received to the questions circulated made it abundantly clear that corrugations were not caused by (*a*) electrolytic action, (*b*) rolling stock (per se), (*c*) driving and braking, (*d*) soft rails, or (*e*) resilient tracks; but that whatever the real cause might be it was aggravated by (*a*) impact and vibration, (*b*) hard rails, (*c*) rigid beds, and (*d*) curvature.

ELECTRIC SHOCKS.

SOME interesting information regarding the danger of electricity is given in the "Lancet" by Dr. Reginald Morton, president of the Section of Electro-Therapeutics in the Royal Society of Medicine, who states that practically no shock, however severe, need necessarily prove fatal. There are, he says, only two fundamental facts that need be impressed upon the minds of everyone. The first is that death from electrical shock is only an apparent death at first; and secondly, whatever the conditions or severity of the accident, there is practically always a time, varying from a few minutes upwards, during which it is possible to resuscitate the victim by artificial respiration if resorted to at once. So important is it to commence artificial respiration quickly that it is the first duty of the bystander to see to this before everything else. He must not leave the victim to summon medical aid—it may be too late by the time the doctor arrives—but he should send for medical assistance if there is anyone else present. If the victim has fallen clear of electrical contact first aid may be given at once, but if he remains in contact with the circuit the first step is to get him free. This is dangerous to the rescuer unless care is taken, but the necessary precautions are simple enough for any voltage likely to be encountered by the public—the highest being that used for railways and tramways, about 600 volts. If, then, the victim remains in contact with the circuit, his body must not be touched by his rescuer, but the latter may pull him out of contact by hauling on the clothing, or he may take off his own coat, insert his hands in the sleeves and then handle the victim, with little or no risk to himself. Almost any article of clothing or material may be used provided it is dry and of moderate thickness. Artificial respiration must be persevered with for at least two hours, or until the patient revives; in many cases it may be only a few minutes. After return to consciousness complete rest is essential for a day or two, and under no circumstances must the man be allowed to return to work at once, as he may wish to do if the shock has been a light one. With the prompt application of first aid practically every victim can be revived, and of these nearly all will make a complete and permanent recovery provided they were previously in a normal state of health.

NEW DIESEL-DRIVEN PUMPING INSTALLATION AT RUGBY WATERWORKS.*

BY R. A. PFLEIDERER.

BEFORE discussing the subject which forms the title of the paper, a brief description of the general system of water supply will be given. The water is drawn from two sources: (*a*) A well in Barby Road; (*b*) the River Avon.

The well in Barby Road is not a natural one, but is supplied from a system of drainage pipes or collectors which drain parts of the Hillmorton and Bilton districts. The collectors discharge their waters into a filter bed, and from there the water runs into a well from which the pump suction is taken. The water is delivered into the tank on the tower which is prominent from the road. In summer time this source is dried up, so that then the whole demand is met by the other works. The work required to deliver 1,000 galls. into the tower from Barby Road is, of course, much less than that required to deliver the same quantity from the River Avon, which is about 100ft. below Barby Road, hence a saving in cost has been effected by pumping all the water available from the higher-lying source. The low running costs of the Diesel engine will, however, transfer the whole of the pumping to the Avon Waterworks.

The Avon is made to flow through a reservoir provided with sluice valves to keep it at a certain level. This reservoir is situated near the British Thomson-Houston Works. The water flows by gravity to a circular dirty-water tank through a 24in. culvert, and thence by means of sluice valves to any of the three large filter beds. From here it passes through either of two smaller filter beds and thence to either of two large brick-built clear-water tanks. The pumps take their suction from here, and deliver into the town mains. The suction pipes are fitted with non-return valves and strainers. The head of water against which the pumps work is maintained by the column of water from the waterworks to the tower in Barby Road.

The difference in level is from 168ft. to 192ft., according to how full the tank on the tower may be. The resistance to the flow of water throughout the pipe system increases this head according to the rate at which the water is flowing. The Barby Road and Avon Waterworks pump simultaneously into the same town mains, from which springs a network of smaller mains covering Rugby, and the districts of Bilton, Hillmorton, Brownsover, and Newbold. This network terminates in the supply pipes to the individual houses, the population served numbering about 25,000.

The steam plant whose work the Diesel engine takes over consists of: (*a*) Two boilers, one of the Lancashire type and the other of Babcock & Wilcox water-tube type; (*b*) two steam engines and pumps, one a Worthington triple-expansion set with an output of 50,000 galls. per hour and the other a Haythorne & Davy with an output of 30,000 galls. per hour; (*c*) feed-water softener; (*d*) two boiler feed pumps; (*e*) two condensers; (*f*) two air pumps.

Before the introduction of this steam plant, there were a high-speed steam set giving 10,000 galls. per hour and a beam engine set giving 14,000 galls. per hour. The latter also drove a small centrifugal pump by belting. The duty of this pump is to take the water from the river in times of flood, when it is very muddy, and discharge it into the reservoir, where the mud can settle before the water passes on to the filter beds. This pump will in future be driven by a small 15 b.h.p. semi-Diesel "Bolinder" engine, using the same fuel oil as the main engine.

The new installation is designed for an output of 80,000 galls. per hour against a head of 260ft., with an overload capacity of 100,000 galls. per hour against a head of 220ft.

* Abstract of paper read before the Rugby Engineering Society, December 17th, 1912.

The plant consists of a "Victoria" turbo-pump, made by Messrs. Willans & Robinson, Ltd., driven by a Willans-Diesel engine through mechanical gearing. The pump runs at a normal speed of 1,115 revs. per minute and the engine at 220 revs. per minute. The general arrangement of the engine-room is shown in plan and elevation in Figs. 1, 2, and 3. It will be seen that the whole plant, including all the auxiliaries with the exception of the main fuel storage tanks and the exhaust silencer, are in the engine-room itself, which shows the compactness and convenience of the Diesel plant as compared with steam power with auxiliaries, or with a gas plant with its spacious producers.

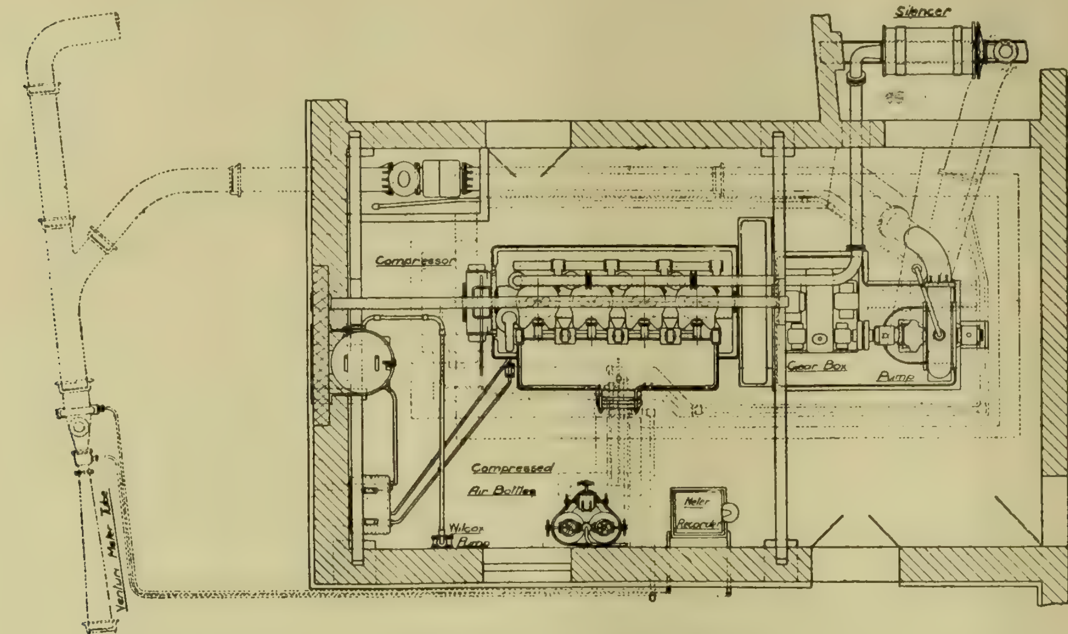


FIG. 1.—ENGINE ROOM, RUGBY WATERWORKS.

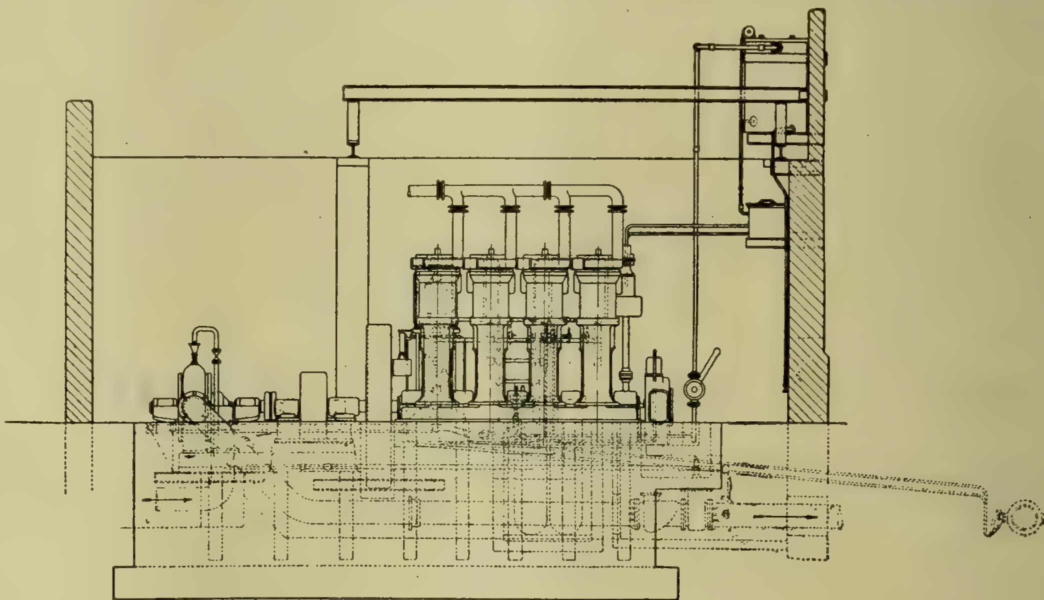
The fuel as purchased is delivered in the oil company's special railway wagons. From the wagon it is transferred to the Council's road oil cart by means of a 2½in. semi-rotary Wilcox pump, which, together with a hose pipe and its unions, forms part of the equipment of the cart. The cart is drawn alongside the storage tanks, into which the oil is pumped by means of the same Wilcox pump. The hose is coupled to a connection in the tanks similar to connections for fire hose. From the bottom of the storage tank the oil, after passing through a strainer, is led underground to the suction of another Wilcox pump fixed to the engine-room wall. The pump delivers the oil into the service tank, which holds sufficient for 18 hours' run at continuous full load. This service tank is provided with a float and indicator to enable the level of the oil to be observed by the man working the pump. From here the oil is fed by gravity, the quantity being controlled by a ball valve, into the fuel filter tank, where the oil has to pass through a fine filter before falling again by gravity to the fuel pump suction, whence it is fed into the engine in quantities regulated by the governor. The products of combustion escape from the engine to the atmosphere through the exhaust pipes and silencer, without smokiness.

The complete installation divides itself into the following three chief items: (1) The engine and its auxiliaries. (2) The gearing. (3) The pump.

The Pump.—This is a standard "Victoria" type manufactured by Messrs. Willans & Robinson, Ltd. It is a two-stage pump giving at a speed of 1,115 revs. per minute a normal full load output of 80,000 galls. per hour against a head of 260ft. The leading features of the design and manufacture are: (*a*) Absence of pressure stuffing-box and end-thrust bearing, resulting in increased efficiency, absence of gland troubles and allowing a more compact design. This is accomplished by means of an extremely simple patented balancing device which automatically maintains a perfect axial balance and at the same time keeps the water in contact with its stuffing-box at quite a low pressure. (*b*) The care and accuracy bestowed on the manufacture of the impellers and guide wheels. What might at first sight seem trivial inaccuracies in these vital parts may in practice give rise to appreciable shock and consequent loss in efficiency and durability.

The principle of the turbo pump is simplicity itself. Water enters at the centre portion of the "flyer" or "impeller," is thrown by centrifugal action along the passages formed by the vanes, leaving the vane tips at a certain velocity, and entering the fixed guide passages without shock. The diaphragms and guide wheels are so made that the water passes from the outside of the passages down between the diaphragm and guide wheel, and into the middle portion of the next flyer, and so on. From the last guide passages the water passes to the annular chamber communicating with the delivery pipe.

The impellers and guide wheels are cast in bronze, while the diaphragms are of cast iron. The shaft is of high-grade nickel steel, and is provided with renewable bronze bushes to protect it from the wear due to the packing. The bearing housings are cast in one piece with the end covers, which fit cylindrically into the body, thus ensuring perfect alignment. The bearings are designed for high speeds and provided with ring lubrication. The pump body is of cast iron, lined with special bronze to protect it from acid water and from rusting.


FIG. 2.—ENGINE ROOM, RUGBY WATERWORKS.

The theory of the pump is that of a water turbine reversed. The greatest source of inefficiency is the loss in eddies at the discharge from the vanes. It is in the means adopted to minimise these eddies, and to convert to useful work as much as possible of the kinetic energy at the tips of the vanes, that centrifugal pumps differ. There are three arrangements adopted for this purpose: (*a*) Spiral discharge chamber; (*b*) arrangement of discharge chamber to give a whirlpool of free mobility; (*c*) provision of fixed wheels carrying guide passages.

In the spiral chamber design the sectional area is increased uniformly towards the delivery pipe, and thus gives approximately continuous stream lines and minimises eddy

loss. In the whirlpool chamber design the water is discharged into the chamber and there forms a vortex or whirlpool in which the velocity varies inversely as the radius. In this way the velocity is least, and therefore the pressure greatest at the outside, from which the delivery is taken. In the guide wheel type the water is discharged from the impeller into fixed guide passages, whose area across the direction of flow gradually increases and thus converts a good part of the kinetic energy into static head. The last method is adopted in the pump in question.

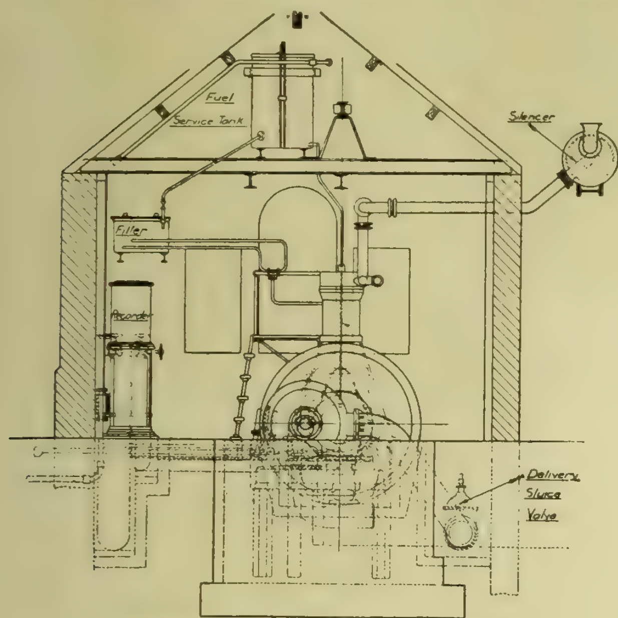


FIG. 3.—ENGINE ROOM, RUGBY WATERWORKS.

The Reduction Gearing.—This is rigidly coupled to the flywheel, but there is a flexible coupling on the high-speed shaft between the gear box and the pump. The slow speed shaft runs normally at 220 revs. per minute (*i.e.*, normal speed of the engine), and the high-speed shaft, and therefore the pump, runs at a speed of 1,115 revs. per minute. The gear is of the double helical type giving no unbalanced axial thrust. The gear box is bolted on the same baseplate as the pump. The main gear-box casting forms the grease chamber in which the gears run, and is faced on the top to carry the bearings, and faced also for the gear-case cover. The bearing on the engine side of the low-speed shaft is specially designed to take its share of the weight of the flywheel, and thus acts as an outboard bearing. The large wheel is cut from a high-carbon steel casting, and is keyed to the shaft. The pinion is also of steel, being in one piece with the high-speed shaft.

The auxiliaries will be considered next. They are: (1) Air compressor; (2) compressed air bottles; (3) silencer; (4) main storage tanks; (5) fuel service tank; (6) fuel filter tank; (7) Venturi meter and recorder.

The Air Compressor.—This was manufactured by Messrs. Reavell & Co., of Ipswich. It is of the three-stage type with two low-pressure, one intermediate, and one high-pressure cylinders, and is driven direct off the engine crank shaft, the body being bolted to a facing on the engine bedplate. All pistons are driven from the one crank pin. This makes a very neat and compact design, the big ends of the connecting rods being cut away at an angle, and held on to the gun-metal bush (which fits over the crank so as to keep it free from wear) by means of gun-metal straps. The compressed air, in its passage from the low-pressure to the intermediate-pressure cylinder, and from the intermediate-pressure to the high-pressure cylinder, is made to pass through water-cooled coils.

Blow-off valves are attached so as to ease the pressure whenever it should be higher than desired. One is fitted to the low-pressure delivery and the other to the intermediate-pressure delivery chamber. The valves and water jackets can easily be inspected by removing the cast-iron inspection doors, which form part of the water jacket. There are no suction valves in the low-pressure cylinders, ports being cut in the gudgeon pins and into the piston casting in such a way that during the suction stroke atmospheric air enters freely into the cylinder. The angular motion of the connecting rod closes the ports at the end of the suction stroke, so that the air is compressed and forced through the delivery valves. By eliminating these suction valves the air is drawn in without appreciable resistance at atmospheric pressure, thus increasing the volumetric efficiency. There are a number of spring-loaded mushroom type delivery valves to each cylinder, which give better results in operation than would be the case with a single valve.

Compressed Air Bottles.—These have to serve two purposes. Firstly, they must store air from the compressor, to blow in the fuel oil against the compression in the engine cylinder. For this purpose one bottle is used. Secondly, air must be stored to start the engine from rest for two or three turns, after which firing takes place in the cylinders and the engine runs up to speed. For this purpose two bottles are provided, each much larger than the "blast" bottles. One of these larger bottles is used in the ordinary way for starting, and is filled again to its full pressure during the first few minutes' run. The other large bottle is a reserve, in case, by carelessness, the one starting bottle may be allowed to run down. The arrangement of the bottles and their valves is shown diagrammatically in Fig. 4.

During ordinary running air is compressed by the compressor and charged into the blast bottle, whence it goes to the fuel valve, but connections are so arranged that after starting up, the starting air bottle can be pumped to its full pressure from the compressor, viz., the blast bottle. To maintain the correct blast pressure for the engine, which is lower than the starting air pressure, during this time, the blast is throttled before entering the blast pipe.

The Silencer.—This consists of a cast-iron cylinder having two plates transverse to the axis, each having holes arranged to break up the flow of the exhaust into eddies.

The Main Storage Tanks.—There are two of these, 7ft. diam. and 17ft. in length. The total storage is thus 1,300 cub. ft., or 8,100 galls., or 34 tons. This is sufficient for six weeks' continuous full-load working 24 hours a day, or about three months' working at the present load factor of the station, taking the normal output of the set as full load. The tanks are provided with gauge glasses, manholes, connections for hose for filling, drain cocks for the purpose of cleaning, and air cocks to allow air to escape during filling and enter as oil is drawn off. They are made of $\frac{5}{16}$ in. riveted steel plates, and are supported on cast-iron stools, which in turn rest on concrete piers sunk into the ground.

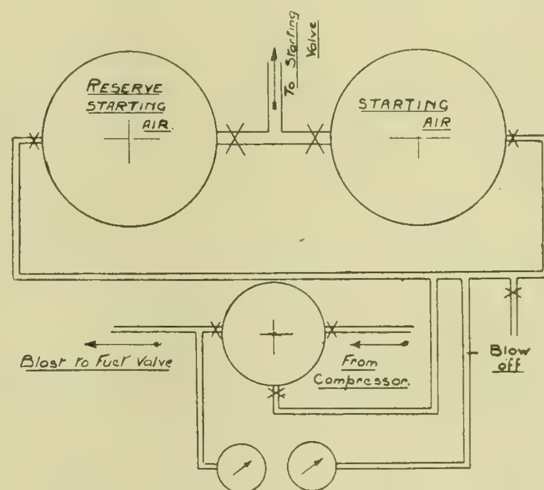


FIG. 4.—DIAGRAM OF AIR BOTTLES AND VALVES.

The Fuel Service Tank.—This is in the engine-room, resting on girders built into the wall. It is a plain cylindrical galvanised tank, holding about 18 hours' continuous full-load supply, or about 36 hours' supply under present running conditions. It is provided with a float and outside indicator, so that the level can be seen from the engine-room floor.

The Fuel Filter Tank.—This tank is in two compartments, one holding crude oil and the other paraffin. The outlet pipes from these compartments run to a three-way cock and thence to the fuel pump suction, so that the engine can be

switched on to crude oil or paraffin. The level in the filter tank is maintained by an ordinary cistern-type float valve. The filter pad itself is a disc of felt, and has very little filtering to do, as the oil passes through a very fine gauze filter before entering the outlet pipe from the main storage tank.

The Venturi Meter.—This is of the usual type, made by Geo. Kent, Ltd., with a recorder, showing on a diagram the rate of flow in the main delivery, and also showing on dials the number of gallons delivered from the time it was set at zero.

The Engine.—Like many other inventions, the Diesel engine was not originally planned and designed in the form with which we are now familiar. Dr. Diesel aimed at producing an engine to work on the Carnot cycle, and intended to use coal dust as the fuel to be burnt in the cylinder. He hoped also to do away with water-cooling altogether, thus eliminating a large heat loss.

With such an ambitious programme, it is not surprising that numerous difficulties arose, altering the proposition

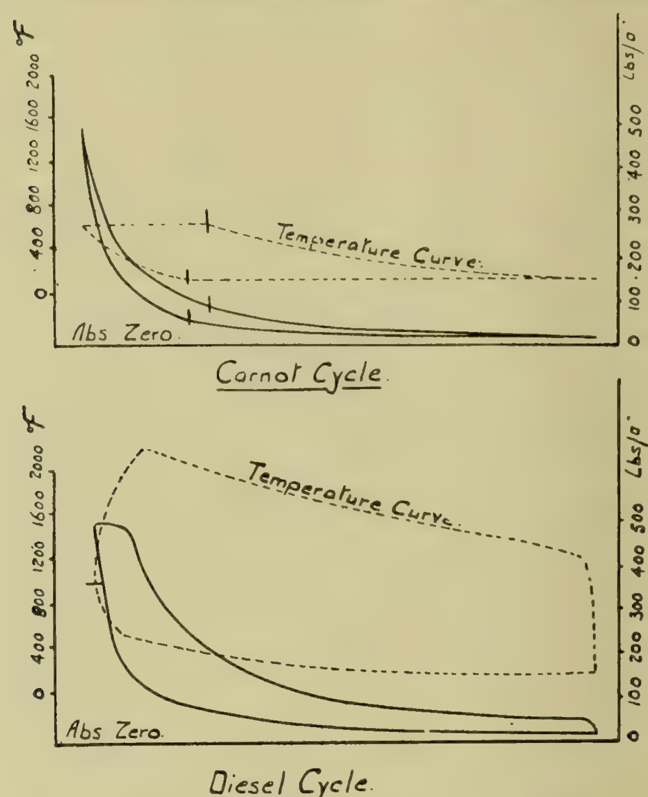


FIG. 5.—CYCLES AND TEMPERATURE CURVES OF IDEAL CARNOT ENGINE AND DIESEL ENGINE.

very materially. Water-cooling was soon found to be essential; coal dust had to be replaced by oil, and isothermal combustion was found to be unattainable and constant-pressure combustion employed. Eventually, after much experimental work by Dr. Diesel, in conjunction with the Maschinenfabrik Augsburg-Nürnberg, the Diesel cycle, as now familiar, was embodied in the historical 20 b.h.p. engine built at Augsburg in 1897—five years after the first application for patent in Germany and other countries. In 1898 the Nürnberg company sold the first commercial Diesel engine, which gave 60 b.h.p., and which is still in satisfactory working order.

The cycles of the ideal Carnot engine and the Diesel engine are shown, together with their temperature curves, on Fig. 5. They are drawn to the same pressure, volume, and temperature scales. The Diesel and Carnot cycles are drawn for the same maximum pressure and the same cylinder volume, and therefore for the same size and strength of cylinder. Thus the areas of the cycles are in proportion to the power developed by the two engines at the same speed. It will be seen that by departing from the ideal Carnot cycle and sacrificing efficiency much greater powers can be developed than would be the case in the ideal engine of the same proportions.

The engine under consideration is the vertical single-acting four-stroke land type. The following is the sequence of strokes, beginning at the suction stroke:—

(1) Downward stroke. Atmospheric air is admitted to the cylinder.

(2) Upward stroke. The air is compressed to its maximum pressure before the introduction of fuel.

(3) Downward stroke. The fuel is injected into the cylinder at the top dead centre, with the compression pressure at about 500lbs. per square inch. Combustion takes place spontaneously at the compression temperature, and then expansion for about 85 per cent. of the stroke, after which the exhaust valve opens and allows the products of combustion to escape.

(4) Upward stroke. The products of combustion are expelled from the cylinder through the exhaust valve.

In this cycle three points stand out clearly. The first is the absence of fuel during the whole of the compression stroke. This is one of the great advantages of the Diesel engine over the gas engine, and is of paramount importance in view of the fact that in a very large proportion of the troubles which have arisen in gas engine practice, the cause has been pre-ignition. The second point is that fuel has to be injected into the cylinder against a compression of 500lbs. per square inch. This is accomplished by the use of highly-compressed air which blows the oil into the cylinder immediately the fuel needle valve is opened. The third point is the absence of any external means of ignition owing to spontaneous combustion at the compression temperature. This rids the station engineer of a great number of minor troubles which attend the use of all ignition devices.

It is worthy of note that the use of compressed air to inject the fuel into the cylinder gives a means of increasing the amount of air for combustion at higher loads. The air drawn in by the piston is constant at all loads, and the amount of air which passes with the fuel into the cylinder is regulated by the blast. Thus, at high loads, the blast pressure is raised, and more air enters the cylinder than at low loads.

It is in the design of the fuel valve and fuel pump that the Diesel engine presents features peculiar to itself, the other parts following the accepted practice of internal-combustion engines with comparatively unimportant modifications.

In order to get spontaneous combustion at the compression temperature, the oil must be injected into the cylinder in the form of a fine spray. For this purpose the oil is made to pass through what is known as the pulveriser or atomiser before arriving at the needle valve admitting it to the cylinder. The pulveriser consists of several rings with a number of small holes drilled in them. Two-pitch circles are used so that neighbouring rings do not have holes directly opposite to each other. From these rings the oil passes on to the pulveriser cone, which is a cone with grooves cut on its curved surface. The cone fits into a seat leaving the grooves as oil passages. The effect of the rings and cone is to break up the fuel as efficiently as possible before it is blown into the cylinder. Perfect combustion in the cylinder can only be obtained with a correctly designed pulverising arrangement.

The engine, which has four cylinders of the A frame type, in which the upper part of the crank casing is in one casting with the cylinder. This is the accepted type for general land work and low speeds. Briefly, the action of the engine is as follows: The energy developed in the cylinder is transmitted by the piston and connecting rod to the crank shaft, which has a gear wheel keyed on to it, driving a vertical shaft which again by skew gearing drives the cam shaft operating the valve levers. There is no external crosshead, the piston being of the trunk type forming its own guide.

The bedplate forms the lower part of the crank chambers, and is bored to receive the main bearings. It is faced and studded on top to receive the A frames and at the end for the compressor body. The crank shaft is of forged steel, and necessarily of a large diameter on account of reversal of stress and the greater inequality of torque than in the case of steam engines. There are four cranks, the first and fourth in the same direction and 180° from the second and third. This arrangement gives an impulse every half-revolution of the

shaft. The main bearings are of cast iron lined with white metal and provided with ring lubrication.

The trunk piston is of cast iron, with a through hole provided for carrying the gudgeon pin. It is not separately cooled on this size of engine. The connecting rod is a solid forging of carbon steel with big end bearings lined with white metal and made in halves, with shim plates for the purpose of taking up wear. The small end carries a bearing in halves, made of a special phosphor-bronze and provided with an adjustment for taking up wear.

The cylinder cover is of cast iron arranged to take the valve seatings. The fuel valve is in the middle and the exhaust and suction valves placed symmetrically on each side. There is also the starting valve placed between the fuel valve and suction valve, and set forward a little. The remaining space is taken up by the cooling water. The whole is necessarily of a heavy liberal design on account of the large forces it has to withstand. Through holes are provided for the A frame studs, by means of which the covers are held on. The cam shaft, which is driven by the crank shaft through the vertical shaft by skew gearing, is carried on white metal bearings. The brackets carrying the bearings are bolted on to faces on the A frames. The cams, which are all ground to a former, are keyed on to the cam shaft.

The valve levers which actuate the valves carry case-hardened rollers which run on the cams. The fulcrum for the levers is a short shaft for each cylinder, and is carried by pillars bolted to the cylinder covers. The starting valve lever and fuel valve lever are carried by eccentric bushes on the fulcrum shaft, so arranged that by means of a lever either the fuel valve or the starting air valve may be in action, but not the two at the same time. The timing of the valves is assured by marking the teeth on the skew gears on the vertical shaft with the corresponding teeth into which they fit on the crank shaft and cam shaft respectively. For the last fine adjustment of the timing of the fuel valves, the cam operating the fuel valve lever may be slightly advanced or retarded during the timing-up process, but is locked permanently when once properly adjusted. The flywheel, which is 3½ tons in weight and 7ft. 4½in. diam., is made in one casting. Teeth are cast inside the rim for the pawls of the barring gear for barring the engine round to any desired position.

The fuel pump and governing are, of course, vital features of the engine, and are arranged as follows: On the vertical shaft are two eccentrics, one rigidly fixed to the shaft and the other to a sleeve which rotates with the shaft and the governor, but which is capable of an angular movement relative to the shaft. As the balls fly out the sleeve is turned relatively to the shaft, and therefore relatively to the fixed eccentric. The fixed eccentric operates the pump plunger, which thus has a definite fixed stroke. The other eccentric operates a trip plunger, which also has a definite fixed stroke, but whose timing relative to the pump plunger is controlled by the governor. This trip plunger lifts the suction valve of the fuel pump off its seat during part of the stroke, thus by-passing the fuel back to the suction. The governor controls the timing of this trip plunger and therefore controls the length of the effective portion of the pump plunger stroke, thus regulating the amount of oil given to the cylinders. A handle is provided which when set to a certain position lifts the pump suction valve off its seat independently of the trip plunger, thus shutting down the engine.

As with all governors, the sensitiveness can only be increased at the expense of hunting at light loads, or vice versâ; hunting at light loads can only be minimised by increasing the governing range. Thus a compromise has to be arrived at which is most suitable to the conditions of service. Hand regulation is provided to vary the speed while running between 220 and 182 revs. per minute, to enable the pump to run at a lower speed, and thus maintain a better efficiency at low loads.

The quantity of water discharged by the pump at maximum efficiency is proportional to the speed, and the head is proportional to the square of the speed, and hence the water horse-power is proportional to the cube of the speed. Thus the pump can be made to give ·565 of its full load at practically full load efficiency by reducing the speed from 220 to 182 revs. per minute.

The cooling water supply is taken off the water mains and delivered to a pipe with branches to the bottom of each water jacket. From the top of the water jackets it passes into the cylinder covers, and from the top of these it discharges as an open stream into a cast-iron funnel connected to the outlet pipe. A separate water connection is made for each cylinder and one for the compressor. The open stream allows one to take the temperature by the hand, or more accurately by means of a thermometer.

The summary of the engine test figures will be found tabulated. It is customary for the makers to ask for a margin of 5 per cent. on the consumption figure when the engine is still "stiff," and the bearings have not yet got the perfect running surface which comes with a few weeks' running. It will be noted, however, that the consumption is well within the guarantee without deducting this 5 per cent. Some of the quantities in the table call for comment. The value of $\frac{\text{B.H.P.}}{\text{I.H.P.}}$ is seen to be a fraction under 80 per cent., which at first sight seems remarkably poor, if thought of in the light of a mechanical efficiency. The reason is this: part of the power delivered to the crank shaft is absorbed in the air compressor,

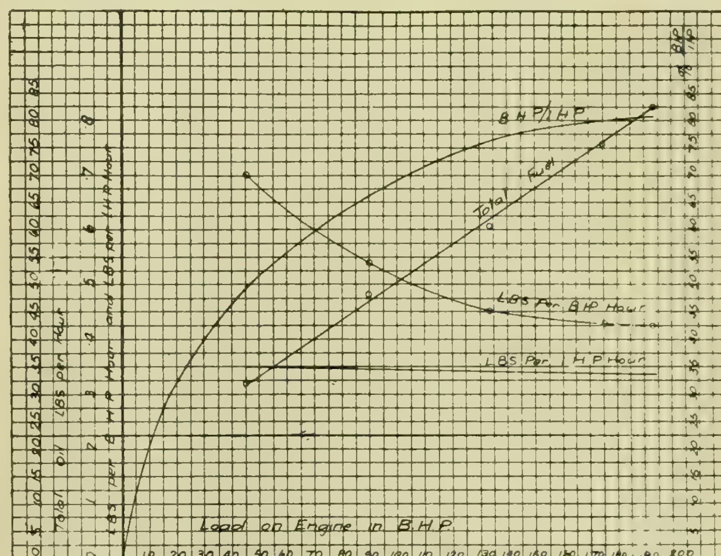


FIG. 6.—FUEL CONSUMPTION CURVES OF DIESEL ENGINE AT RUGBY WATERWORKS.

so that the effective brake horse-power as measured by the brake is less by that amount than the horse-power delivered to the shaft.

The same remarks apply to the values given to the thermal efficiency on a brake horse-power basis. More important than either of these is the fuel consumption per brake horse-power, which figure is of paramount importance in the commercial proposition, of a new plant. It is to be carefully borne in mind that these figures are sometimes stated on a basis of shaft horse-power without subtracting the air compressor work, and sometimes on a basis of effective brake horse-power. Unfortunately, on the Continent the former is adopted, whereas British engineers prefer the latter. As a consequence one is too liable to fall into the trap of thinking that the continental makers can achieve efficiencies beyond the reach of British manufacturers. Though stress is laid on this point, from a technical standpoint it is merely a matter of definition. It may be of interest in this connection to remark that the only, or nearly the only, engineer on the Continent who upholds the British acceptance of the term "mechanical efficiency" as being the ratio of the effective brake horse-power to the indicated horse-power is Dr. Diesel himself.

The fuel consumption may be given in terms of the steam utilised in the main engine or turbine without either including the steam required for auxiliaries, and without subtracting from the power developed the amount of power required to drive the auxiliaries, which may or may not be electrically driven. The curves of total fuel, fuel per brake horse-power, $\frac{\text{B.H.P.}}{\text{I.H.P.}}$, and thermal efficiency on brake horse-power basis are plotted against brake horse-power (see Fig. 6).

LOAD.	10 % Over-load.	Full.	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$
Load on brake, lbs.	528	480	360	240	120
Revs. per minute	220	220	224	226	228
Brake horse-power	193·5	176	134·4	90·4	45·6
Average mean effective pressure in each cylinder	105·1	96·75	75·4	59·4	39·15
Indicated horse-power	239·9	222·2	175·0	139·8	92·6
B.H.P. / I.H.P.	80·6	79·3	76·7	64·7	49·2
Blast pressure, lbs. per square inch	1030	910	775	660	560
Average of maximum pressure in each cylinder	510	474	451	454	450
Total oil lbs. per hour	82·5	75·9	60·9	48·8	32·0
Total oil lbs. per I.H.P. hour	0·344	0·341	0·348	0·349	0·346
Total oil lbs. per B.H.P. hour	0·426	0·431	0·453	0·541	0·701
Guarantee, lbs. per B.H.P. hour	—	0·47	0·49	0·57	0·76
Thermal efficiency on I.H.P. basis	41·1	41·3	40·6	40·5	40·8
Thermal efficiency on B.H.P. basis	33·2	32·8	31·2	26·1	20·1

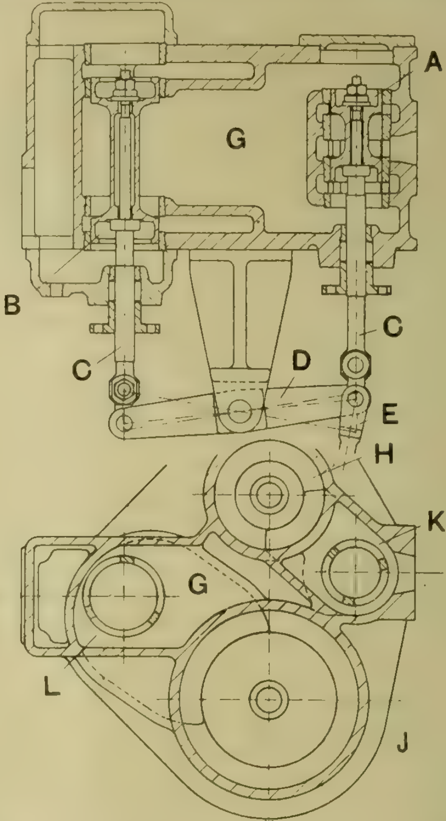
Advantages of the Diesel Engine.—The first consideration of a station engineer in deciding what plant to install, is the cost of his power when the plant is put to work. The great question of cost involves a very large number of variables, so that to be guided by statistics alone is impossible. Full appreciation of local conditions is essential in comparing relative economics of different power systems. The capital cost of buildings and plant taken together is sensibly the same for steam, gas, and oil power, local conditions alone being able to place them in order of merit. The fuel costs for an engine of 150 to 200 b.h.p. are less for the Diesel set providing that oil is not more than about five times as costly as coal, weight for weight. This is based on continuous full load running, and the economy of the Diesel engine becomes more marked as the load factor falls off. For intermittent running the Diesel engine scores a very great advantage in having no stand-by losses. It can be started up and put on full load within a minute. The cost of labour is of course less for the Diesel engine than for steam plant. Owing to the somewhat recent introduction of the Diesel engine, a driver's wages are higher than a steam engine driver's, but the stoker's wages are saved, leaving a big balance of economy with the Diesel engine. Where water is scarce, the Diesel engine has an advantage of great importance, only requiring 3 galls. to 4 galls. per brake horse-power hour, whereas a modern condensing steam engine requires at least 60 galls. per brake horse-power hour. In a locality subject to dry seasons this is a point of great weight. With regard to stores, maintenance, repairs, and depreciation taken together the Diesel engine shows to disadvantage only when compared to a steam engine by itself. When the boiler and auxiliaries are taken into account the tables are reversed. For the size and duty of the plant at the Rugby Waterworks, the Diesel engine is a very sound economy.

The author's thanks are due to Messrs. Willans & Robinson, Ltd., for information placed at his disposal and to the Rugby Town Council for permission to read this paper on their plant.

VALVE ARRANGEMENTS OF MULTIPLE EXPANSION MULTIPLE CRANK ENGINES.

In a compound engine with receiver space and separate high-pressure and low-pressure valves both controlled by an automatic expansion crank shaft governor, important advantages are secured in relation to prompt and close control of speed, great steam economy over a wide range of loads, and large overload capacity owing to the automatic expansion and compression governing, while these cannot be secured with throttle governing, or even with automatic control of expansion in the high-pressure cylinder. To secure these advantages in an engine with cylinders side by side Mr. William Sisson, of Hucclecote, Gloucester, has designed and patented the arrangement illustrated, which is shown applied to a double-acting compound double crank engine with cylinders side by side and provided with piston valves.

Referring to Fig. 1, the high-pressure valve A and the low-pressure valve B are shown with their respective valve spindles C connected by links and joint pins to the rocking lever D. Motion is transmitted to the rocking lever D from the eccentric of the crank shaft governer by means of an eccentric strap connected to the eccentric rod E, and this motion is imparted to the two valve spindles and valves linked up to the rocking lever. The motion of the two valves thus obtained being opposite in phase enables the distribution of steam to be arranged so that the admission of steam to the high-pressure cylinder is controlled by the inner edges of the high-pressure valve A, and the exhaust steam from the high-pressure cylinder into the high-pressure receiver G is controlled by the outer edges of the valve A. The exhaust steam from the high-pressure valve constituting the steam supply from the high-



VALVE ARRANGEMENT OF MULTIPLE EXPANSION MULTIPLE CRANK ENGINES.

pressure receiver G to the low-pressure valve is likewise controlled in its admission to the low-pressure cylinder by the inner edges of the low-pressure valve B and the exhaust by the outer edges thereof. In Fig. 2 is shown the high-pressure cylinder H and the low-pressure cylinder J so placed in relation one to another that there is only sufficient space between the walls of the cylinders to permit the exhaust steam from the high-pressure valve chest K to pass to the low-pressure valve chest L. The placing of the valves A and B one on each side of the centre line joining the two cylinders thus secures a reduced distance between the two cylinders H and J and also provides sufficient receiver space G.

The arrangement described is applicable to various types of double-acting engines of high or moderate speeds and with different types of valve, but is more particularly adapted for use in the case of high speed double-acting engines with steam distribution given by piston valves.

Tramways and Light Railways.—The length of tramways and light railways in England and Wales last year was 2,134 miles; in Scotland, 300 miles; and in Ireland, 163 miles, making an aggregate of 2,597 miles. In 1901 the corresponding lengths were: England and Wales, 1,040 miles; Scotland, 116 miles; and Ireland, 149 miles, making an aggregate of 1,305 miles. Stock, share, and debenture capital last year stood as follows: England and Wales, £63,183,744; Scotland, £7,537,870; and Ireland, £4,003,826, making an aggregate of £74,725,440. The gross receipts last year were: England and Wales, £11,418,936; Scotland, £1,778,490; and Ireland, £579,575, making an aggregate of £13,777,001. The working expenses last year were: England and Wales, £7,207,359; Scotland, £967,210; and Ireland, £326,372, making an aggregate of £8,500,941. The net return upon the capital expended stood last year at barely 3 per cent. per annum

LIGNITE FOR STEAM POWER AND GAS PRODUCER PLANTS.

In a paper recently presented at a meeting of the American Society of Mechanical Engineers, the author, Mr. C. H. Crouch, presented the results of a series of tests to ascertain the suitability of lignite as a fuel for steam power plant and gas producers. The lignite was that obtained from the North Dakota field, which, it is estimated, comprises one-sixth of the known coal deposits of the United States. Numerous proximate analyses were made of samples, the results of which showed the green coal to contain approximately 35 per cent. of moisture, and the dry coal to contain approximately 43 per cent. of volatile matter, 50 per cent. of carbon, and from 7 to 9 per cent. of ash. North Dakota lignite is classed as one of the youngest coals. In appearance it is black when freshly mined, but as it dries it becomes lighter in colour and is often a dark brown. Before it has become sufficiently dry to disintegrate, it somewhat resembles charcoal in that it frequently shows very clearly the grain of the wood and knots of the trees from which the coal has been formed; but upon drying cracks are seen both with and at right angles to the grain. The line of cleavage in breaking is along the grain. Occasionally a piece will be found which has lost its grain and at fracture resembles anthracite in appearance, having a lustre, but this disappears as the moisture is driven off.

Preliminary experiments showed that this fuel may contain (*a*) large quantities of moisture, two coals analysed containing over 35 per cent. of moisture, which is readily given up, causing the coal to crack and disintegrate; (*b*) large proportions of volatile matter, some of which is driven off at comparatively low temperature; and (*c*) a small percentage of ash. These characteristics are very important and must be taken into consideration when designing furnaces and gas producers to utilise it. In the furnace it disintegrates and if burned on grates suitable for a coking coal, it will, when heated to red, run through the grate like so much coarse sand, especially if it be disturbed with a slice bar. Thus it will be seen that it should be burned on a grate with small openings and with a strong draught, for when it disintegrates it settles or packs down, restricting the air passages. One would also expect, since it contains a large proportion of volatile matter, that fire-brick arches or dutch ovens would be desirable in burning it under boilers.

Evaporative Tests. — Evaporative tests, using North Dakota lignite under the boilers, were made in the mechanical laboratory of the College of Mechanical and Electrical Engineering at the State University of North Dakota. This plant consisted of two 70 h.p. horizontal fire tubular boilers, one of which was equipped with an automatic stoker and a dutch oven 7ft. long projecting out in front of the boiler, while the other was provided with an ordinary furnace and rocking grates which were suitable for burning eastern bituminous coals. After several preliminary experiments, this last-mentioned furnace was modified by placing fire-brick arches or tiles over three-fourths of the grate and by substituting perforated plates for the rocking grates, the perforations being ½in. diam. and 35 per cent. of the area of the grate.

The plant was provided with natural draught which was adequate when burning eastern bituminous coal to drive the boilers much beyond their rated capacities, but which proved inadequate when burning lignite. Several tests were conducted, varying from four to ten hours in duration. While they were unsatisfactory in that the boilers could not be driven at their rated capacities, they indicated conclusively that a much stronger draught would be necessary to keep the furnaces at a white heat and to force the boilers to their rated capacities. A small fan was available for producing a forced draught. It was not large enough to supply the necessary pressure, but served its purpose for, with it, the furnace could be kept at a white heat, which was impossible without it. It was not thought advisable, however, to drive the fan at the necessary high speed for any considerable time, and the results obtained with natural draught had to suffice. The author, wishing to confirm the results secured in 1911 by the students, conducted three tests in the spring of 1912, with about the same experience and results. It was clearly demonstrated that with a dutch oven and a mechanical stoker with proper draught conditions, the coal can be economically utilised in a steam power plant.

Table I. gives the more important economic results obtained from these preliminary evaporative tests. For comparison the average of the results of 15 tests made by the U.S. Bureau of Mines with this coal in a specially constructed furnace has also been included.

TABLE I.—*Evaporative Tests.*

Furnace.	Grate Area, Sq. Ft.	Duration of Tests. Hours.	Per Cent. Moisture in Coal.	Dry Coal burned per Sq. Ft. of Grate Surface per hour	Equivalent Evaporation from and at 212 deg. per lb. of Coal as fired.	Equivalent Evaporation from and at 212 deg. per lb. Dry Coal.	H.P. in Per Cent. of Builders' Rating.
Detroit stoker and dutch oven	20·25	10	35·77	12·20	4·22	6·58	67·4
Perforated plate grates with arches over three-fourths of the grate. .	16	12	35·77	14·58	3·638	5·66	54·7
Special furnace used by Bureau of Mines	..	..	43·27	25·18	3·49	6·09	73·9 to 103·3

It will be noted that although the boilers were forced as hard as possible in the tests conducted by the author, they developed only from 54·7 to 67 per cent. of the builders' rated

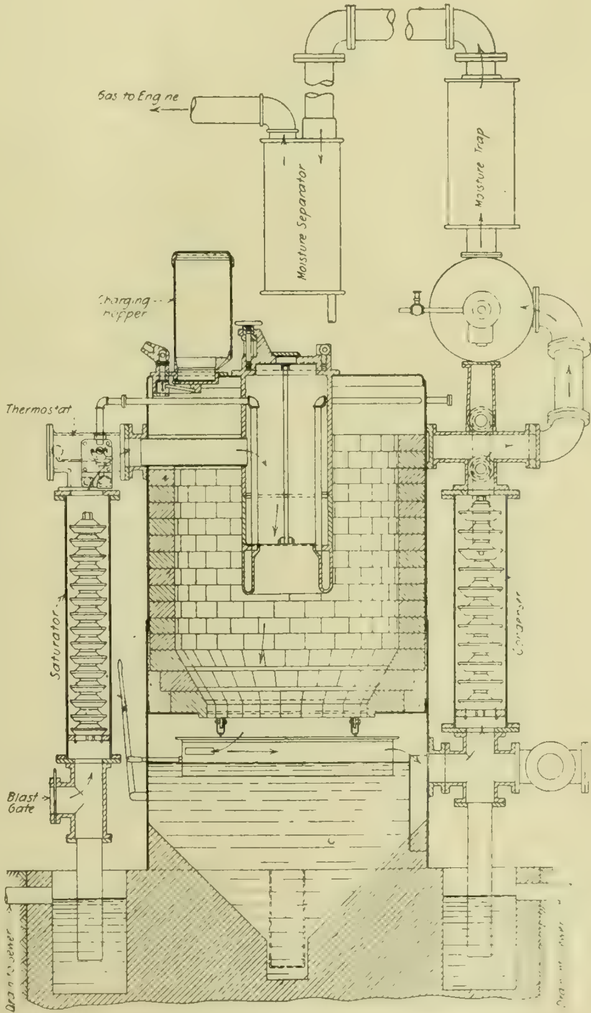


FIG. 1.—SECTIONAL VIEW OF GAS PRODUCER

capacity. In burning the coal on the chain grates under water-tube boilers in the university power plant which had natural draught, a similar experience resulted. The experiment was begun with the furnace at a white heat, but as the lignite was fed into the furnace the fire-brick arches and tile on the water tubes cooled to a much lower temperature and the boiler could not be driven at anything like its normal rating.

Gas Producer Tests. — Experiments with North Dakota lignite in the gas producer were conducted in the same laboratory, the object being to determine the feasibility of using this fuel in a producer gas power plant. The experimental plant

consisted of a 50 h.p. Smith suction down-draught gas producer and a 55 h.p. Alberger tandem producer gas engine belted to a dynamo. The scrubber was driven by an independent motor. In the 1911 tests, the dynamo used to load the engine was a 25 kw. direct-current machine. but for the subsequent tests a 45 kw. direct-current three-wire generator with compensating coils was installed so as to be able to load the engine to its maximum capacity. Fig. 1 shows a sectional view of the gas producer and Fig. 2 a sectional view of the engine.

The engine was loaded by means of a dynamo which supplied current to the university light and power circuit and also to a water rheostat which could be used when there was not sufficient demand otherwise for power to utilise all that was produced. The dynamo was so connected that current could be taken from the main line to drive the generator as a motor in starting up the engine. This made a simple and very satisfactory way of starting the engine which, when started, would speed up, increasing the generated electromotive force, and cause the motor to become a generator supplying current to the line, the load carried by the dynamo being governed by the voltage which was controlled by a hand-regulated field rheostat.

The generator used during the tests Nos. 1-8 inclusive was an old 25 kw. direct-current generator formerly used in the university lighting plant; in tests Nos. 9-18 inclusive a new Fort Wayne machine. This machine started up nicely, but before test No. 12 had been finished, the commutator had become warped or out of true, causing much sparking at the brushes. This was remedied, however, before test No. 13 was run, by turning down the commutator, after which it gave no trouble.

The power delivered to the switchboard by the generator was measured, and the coal consumed per kilowatt-hour at the switchboard determined. It was the original intention to determine the efficiency of the generator so as to get the total power developed by the engine, but time did not permit before the armature of the generator was needed to replace a burned out armature in a motor in the university power plant, so that the windage, friction, and internal losses of the generator used in 1911 could not be obtained. However, since the machine was loaded to nearly its rated capacity most of the time, it was assumed in determining the brake horse-power of the engine that the generator had an efficiency of 90 per cent. and that the belt transmission gave an efficiency of 98 per cent., both of which are probably higher than their true value.

As no means was at hand for measuring or determining the amount of water used by the engine jackets or the gas scrubber in the tests of 1911, accurate records of the power used by the scrubber were not taken. To determine the net power available for outside purposes, it would be necessary to charge against such a plant all of the power consumed by the auxiliary apparatus. In the fall of 1911 a motor-driven triplex pump was installed to supply the jacket and scrubber water, also a more efficient motor was installed for driving the scrubber. In determining the net power available for outside purposes in the tests of 1911, it was assumed that the power consumed by the auxiliaries was the same as during the tests of 1912 when apparatus was available.

In determining the power developed by the engine in the tests of 1912, it was assumed that the belt transmission gave an efficiency of 98 per cent. The losses in the generator were determined by experiments in which the windage, friction, iron, and copper losses were carefully determined and curves plotted showing the efficiency of the generator at various loads. The low efficiency of the generator may doubtless be explained by the fact that the machine was developing but little more than 50 per cent. of its rated capacity.

TABLE II.—*Gas Producer Plant Power Tests.*

No. of Test.	Duration, Hours.	Coal Used.	Moisture in Coal. Per Cent.	Kw. Delivered at Switchboard.*	Power Consumed by Generator.	Brake H.P. of Engine Assuming an Efficiency for the Belt Transmission of 98 Per Cent.	CO_2 Per Cent.	O Per Cent.	CO Per Cent.	H Per Cent.	CH_4 Per Cent.	N Per Cent.	B.T.U. Per Cub. Ft.	Suction in Inches of Water at Engine Throttle.	Suction at Scrubber.	Suction In Pit Below Grate.	Suction at Air Inlet.
		Lbs.			H.P.												
1	8	632	32·9	14·18	—	16·07	—	—	—	—	—	—	—	—	—	—	—
2	8	1017	33·1	21·21	—	24·04	—	—	—	—	—	—	—	—	—	—	—
3	7¼	875	35·9	20·86	—	23·65	—	—	—	—	—	—	—	—	—	—	—
4	27½	2575	16·0	22·64	—	25·66	5·10	4·65	17·58	9·31	2·3	61·06	111·4	—	—	—	—
5	4	425	35·8	21·24	—	24·08	—	—	—	—	—	—	—	—	—	—	—
6	8	850	38·0	21·27	—	24·11	—	—	—	—	—	—	—	—	—	—	—
7	16	1700	36·5	22·67	—	25·70	—	—	—	—	—	—	—	—	—	—	—
8	6¼	500	37·2	18·5	—	20·97	—	—	—	—	—	—	—	—	—	—	—
9	24	2960	20·4	18·3	28·71	29·21	11·9	2·4	11·6	—	—	—	—	15·8	13·6	4·9	0·25
10	9½	1255	20·4	19·36	30·16	30·78	9·2	2·5	16·7	—	—	—	—	20·7	15·2	7·3	0·7
11	11½	1365	20·4	19·87	30·88	31·49	10·8	2·3	14·0	—	—	—	—	21·9	17·4	7·6	0·1
12	12	1125	20·4	19·12	29·82	30·43	10·0	2·6	12·5	—	—	—	—	21·1	16·8	10·7	0·18
13	9¾	1205	35·77	22·78	34·94	35·66	9·8	1·0	10·8	—	—	—	—	23·0	20·0	6·0	0·2
14	5⅓	1072	33·0	21·31	32·91	33·58	—	—	—	—	—	—	—	23·6	18·0	4·61	0·7
15	9	1478	23·35	22·99	35·03	35·74	—	—	—	—	—	—	—	23·4	19·1	4·4	0·5
16	11	1351	23·35	22·88	34·92	35·64	9·13	1·64	14·11	16·53	0·88	57·7	109·85	18·2	16·0	7·5	1·27
17	7⅔	820	23·35	24·54	37·37	38·13	6·08	3·8	10·62	18·97	4·2	56·25	152·7	26·9	20·8	4·7	0·07
18	24	3013	23·35	23·18	35·45	36·17	8·59	3·7	11·7	8·04	4·77	63·18	115·42	28·8	21·7	7·5	0·33

* The kw. consumed by scrubber and pump was 3·71 in all the tests.

Tests Nos. 1 to 8 were made between February 2nd and May 24th, 1911; tests Nos. 9 to 18 between February 6th and May 10th, 1912. In all of these a Smith suction downdraught 50 h.p. gas producer and an Alberger tandem 55 h.p. gas engine were used; while in Nos. 1 to 8 a Westinghouse 25 kw. and in Nos. 9 to 18 a Fort Wayne 45 kw. generator was employed. The lignite coal in Nos. 1 to 8 was from the J. Bruegger mine, Williston, N.D., and in Nos. 9 to 18 from the Washburn Mine, Wilton, N.D. An analysis of samples taken from piles out of doors showed for coal No. 1, volatile matter, 44·2 per cent.; fixed carbon, 50·1 p r cent.; ash, 5·7 per cent.; moisture, 35·9 per cent; for coal No. 2, volatile matter, 43·58 per cent.; fixed carbon, 50.33 per cent.; ash, 6·09 per cent.; moisture, 35·77 per cent.

In determining the coal used during the test, care was taken that the producer was full when the test began and when it ended. The coal charged in the meantime was considered as the coal used during the test. Before starting up the blower for the next test, the producer was poked to make sure there were no large voids and filled as before. The coal charged at this time was called the "standover" losses. A similar method was followed after fire had been "blown up" and the amount needed to fill the producer just before starting the test was called the "starting-up" losses.

At the beginning of the first series of tests, Nos. 1-8, Table II., the apparatus for analysing the gases was broken so that but one analysis of the gas of these eight tests was made. Proximate analyses of the coal used in each test were made to determine the moisture. In the second and third sets of experiments, or those conducted in 1912, a complete analysis of the gases was made. The incomplete determinations of CO_2, O, and CO were made with the Orsat flue gas apparatus. It is interesting to note that the composition of the two coals was almost identically the same.

Tests Nos. 1-8 inclusive were conducted at intervals of from

one to two weeks apart. After a test had been run, the producer was filled and enough coal brought into the building during the following week to run the next test. This enabled much of the coal to thaw out, though frequently coal was charged into the producer in the frozen state. The coal used in test No. 4, however, had been in the boiler-room for some weeks, which caused it to be much drier than that used in the other seven tests, but the author is inclined to believe that the 16 per cent. moisture recorded is much too small. It is possibly due to poor sampling or to the loss of moisture between date of sampling and date of analysing.

These tests were conducted with the idea of getting the maximum power possible out of the engine, but the capacity of the generator limited this, while tests Nos. 8-12 were planned to determine the efficiency of a plant, such as an electric light plant where the load would be variable and the plant operating from but six to 12 hours per day, standing idle the remainder of the 24 hours. For this reason, little effort was made to keep the load uniform. Ammeter and voltmeter readings were taken at half-hour intervals, but the power consumed during these four tests was measured by means of a carefully calibrated watt-hour meter. The power developed during tests Nos. 1-8 was determined from the ammeter and voltmeter readings which were taken every 15 minutes; during tests Nos. 13-18 inclusive, the power was likewise determined, but the readings were taken at intervals of 20 minutes each, the loads in tests Nos. 1-8 and in 13-18 being kept as nearly uniform and as large as seemed feasible.

It was observed that at the engine throttle, in the scrubber suction and in the pit beneath the grate of the producer, the suction increased as the tests progressed, apparently due to

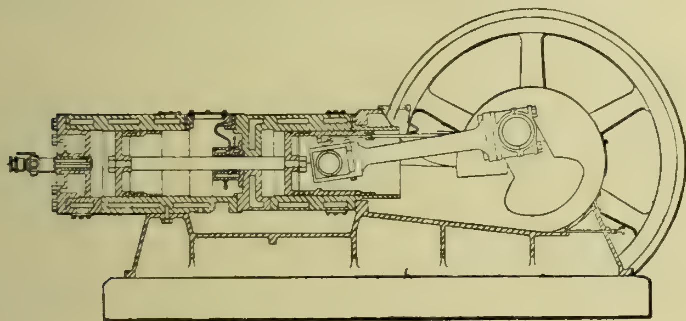


FIG. 2.—LONGITUDINAL SECTION OF GAS ENGINE.

fine ash and clinkers closing up the air passages. This would restrict the gas at the engine, causing its speed to reduce, which in turn would lower the voltage and cause the load to be thrown off automatically.

On one occasion the suction became so great that air was pulled down through the ash conveyer into the bottom of the producer, with a resulting explosion that shook the fire up violently, blowing much fine ash out through the top of the central tube, which happened to be open. The engine automatically threw off its load, the dynamo operating as a motor driving the engine until the spent gases had been exhausted, when the engine immediately speeded up and took on its normal load. The suction at the different parts of the plant was greatly reduced after this explosion, so that it operated satisfactorily during the remainder of the test.

Another source of trouble was that the strong suction would pull ash and fine particles of coal over into the bottom of condensing chamber, which gradually became clogged and finally shut off the supply of gas with the natural results. It is possible that with more experience the producer might be operated to fuse practically all of the ash into large clinkers, which could be removed through the top of the central tube of the producer. A large part of the ash was thus fused, but evidently enough escaped to cause trouble.

The disintegrating action of the coal when subjected to a high temperature caused the coal to settle down and the bed to become dense with restricted air passages, which also tended to increase the suction. Violent shaking of the grate seemed to help reduce this high suction and occasionally the suction would drop to but a few inches when large clinkers were removed.

It was observed in conducting the preliminary tests of 1912, when running tests on successive days using fuel with a large percentage of moisture, that the engine would satisfactorily carry its load during the first five or six hours and then the fire would become chilled and the gas so poor that the engine would scarcely run with no load. It was also observed when this happened that the fire in the producer had burned unevenly, being hotter on one side than on the other, doubtless allowing air to pass down through the bed without burning the coal. This action can perhaps be explained by the fact that the coal which had stood in the producer over night had become sufficiently dry to burn satisfactorily and that the trouble began when the fresh coal charged during the test reached the fire zone, chilling the fire because of its large amount of moisture and causing it practically to die out in certain sections and to become black at the lower end of the central tube where the fire was usually bright when operating under normal conditions. The trouble is one that can be easily overcome either by drying the coal before shipping from the mine or by storing it for a few weeks in a dry, warm place, where it will readily give up a large part of its moisture.

The starting and standover losses of the producer plant were surprisingly small. From a number of records made, it was estimated that the starting-up losses did not exceed 50lbs. even when the producer had been standing idle for one or two weeks and required 35 to 45 minutes to get good gas. The starting-up losses when the producer was operated on successive days were much less, as good gas would be delivered at the engine in from 10 to 20 minutes from the time the blower was started. The engine would often carry full load within 15 or 20 minutes after starting the blower.

The standover losses for 14 different observations covering 867 hours amounted to 3043·5lbs., or an average of 3·3lbs. per hour. The periods of standover varied from 12 to 300 hours, the standover losses for the short periods being more per hour than for the long periods. Taking 777 hours of the longer standover periods, the average per hour of the standover losses was but 1·92lb. per hour. Comparing the starting-up and standover losses of the producer gas plant with those of a steam plant, the author believes the former has a decided advantage over the latter. It should also be borne in mind that a commercial plant would doubtless be much larger than this experimental plant and would give correspondingly better results. Furthermore, it is quite possible that the power consumed in scrubbing the gas was much larger than was necessary, as it was feared trouble would arise from tar getting into the engine.

Doubtless a larger amount of scrubber water was used than was necessary, thus greatly increasing the amount of power consumed in scrubbing the gas. The amount of power consumed by the scrubber could be doubled or trebled simply by increasing the quantity of scrubber water used. No trouble was experienced, however, from tar getting into the engine cylinders. The cylinder head of the engine was removed for inspection from time to time. A small amount of gummy substance adhered to the counterbore of the cylinder, but the cylinder barrel was well lubricated. It was thought that the substance adhering to the counterbore was largely cylinder oil and carbon partially burned, but it may have been partially burned tar. In either event, there was not enough to cause the piston rings to stick or leak or to interfere with the action of the admission and exhaust valves.

Rescue Work in Mines.—The first of a series of lectures, arranged under the joint auspices of the Midland Branch of the National Association of Colliery Managers and the Notts Education Committee, was delivered recently at the University College, Nottingham, by Prof. John Cadman, of the Birmingham University, his subject being "Self-contained Breathing Apparatus for use in Mines after Colliery Explosions and Fires." Prof. Cadman referred to the conditions under which rescue appliances might be usefully employed. Apart from the saving of life, he instanced the utility of the apparatus in other directions, and mentioned that one of the most important undertakings which had been accomplished by rescue apparatus was that at Norton Colliery, in which a gob fire took place. By a self-contained breathing apparatus men had worked in that mine, there being three shifts per day, for nearly six months, and by building stoppages in different districts, and making new air passages, had made the mine workable again. That important piece of work was done without a single accident.

THE CENTRIFUGAL BLOWER FOR HIGH PRESSURES.*

BY HENRY F. SCHMIDT.

(*Concluded from page* 749.)

The Testing and Calculation of Centrifugal Blowers.—The following notes give the readings to be taken, together with the formula used for working out the results of tests, as well as the method of correcting to standard or any selected contract conditions. The data which must be obtained for a complete test of a centrifugal blower comprise (*a*) brake horse-power input to the blower shaft; (*b*) inlet temperature; (*c*) inlet pressure of the air entering the blower; (*d*) barometer reading; (*e*) static pressure in the blower discharge, and temperature in the blower discharge; (*f*) total head blown against, *i.e.*, static head plus velocity by means of a pitot tube placed above the discharge nozzle, and flush with its outlet.

In obtaining the correct inlet temperature to the blower, the temperature should be taken by means of a number of thermometers placed in different portions of the intake duct, so as to obtain a true average temperature, and precautions should be taken to see that no air, other than that passing the thermometers, is entering the blower intake, such as, for instance, air drawn from the basement below the engine-room floor.

FIG. 17.—WORK DIAGRAM, CENTRIFUGAL BLOWER.

The pressure in the blower discharge should be taken at a point as shown in Fig. 18, in which the distance h should be at least four or five times the outlet diameter of the nozzle, in order to avoid a reduction of pressure, which occurs near the nozzle. The temperature also should be taken at a corresponding point by inserting one or more thermometers into the discharge. This can be most conveniently done by sticking the thermometers through rubber inserted in the discharge pipe.

The method of obtaining the total pressure, or static plus velocity head, will be seen from Fig. 18. Either mercury U-tubes or water manometers may be used for measuring the discharge pressure. In either case, the difference between the two sides of the U, *i.e.*, the head in inches of mercury, should be corrected for the temperature of the U-tube. The test nozzles should be made about as shown in Fig. 18; the radius or curvature of the approach to the nozzle should be equal to d, in which case the coefficient of the nozzle is for all practical purposes 100 per cent., or equal to the theoretical discharge. It has been generally agreed that a nozzle coefficient of 98·5 is, if anything, probably 1 per cent. low, and hence has been adopted where it is not convenient to calibrate the nozzle used.

Method of Calculation.—In the following calculation let

P_2 = absolute inlet pressure to the blower in inches of mercury (*i.e.*, barometer reading),

P_1 = total head (static plus velocity) in inches of mercury, plus the barometer reading in inches of mercury,

T_2 = absolute inlet temperature in deg. Fah.

T_1' = temperature in the discharge in deg. Fah. absolute,

T_1 = theoretical temperature in the piping after adiabatic compression,

T_2' = temperature at the mouth of the discharge nozzle.

The work done in foot-pounds per pound of air, in compressing from P_1 to P_2, will be expressed by the formula

$$W = \frac{\gamma}{\gamma - 1} R T_2 \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma - 1}{\gamma}} - 1 \right] \quad \ldots \quad (4)$$

in which R has a value of 1·4065, and the work done per pound of air in expanding from the pressure P_1 to atmospheric pressure in the nozzle will be

$$W = \frac{\gamma}{\gamma - 1} R T_2' \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma - 1}{\gamma}} - 1 \right] \quad \ldots \quad (5)$$

in which

$$T_2' = \frac{T_1'}{\left(\frac{P_1}{P_2}\right)^{\frac{\gamma - 1}{\gamma}}} \quad \ldots \quad (6)$$

Hence, the velocity of the air in feet per second will be

$$V = 8 \cdot 025 \sqrt{\frac{\gamma}{\gamma - 1} R T_2' \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma - 1}{\gamma}} - 1 \right]} \quad \ldots \quad (7)$$

Accordingly, the volume of discharge in cubic feet per second will be

Volume per second $= A V$ ....[8]

in which A is the area of the mouth of the nozzle in square feet times the nozzle coefficient, which, as above stated, for nozzles properly made, is practically unity, or, say, 99 per cent. The total work done in foot-pounds per minute will be equation [4] × equation [8] × 60 ÷ specific volume of 1lb. of air at the barometric pressure and temperature T_2, which may be expressed by the equation

$W_{min.}$ =

$$\frac{\frac{\gamma}{\gamma - 1} R T_2 \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma - 1}{\gamma}} - 1 \right] \times 8 \cdot 025 \sqrt{\frac{\gamma}{\gamma - 1} R T_2' \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma - 1}{\gamma}} - 1 \right]} \times A \times 60}{\frac{R T_2'}{P_2'}} \quad \ldots \quad (9)$$

in which P_2' is the barometric pressure expressed in pounds per square foot absolute. Hence from equation [9] the theoretical air horse-power required to compress the column handled from the pressure P_2 to the pressure P_1 will be equation [9] divided by 33,000, or

FIG. 18.—TEST ARRANGEMENT FOR OBTAINING TOTAL PRESSURE.

air h.p.

$$\frac{\frac{\gamma}{\gamma - 1} R T_2 \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma - 1}{\gamma}} - 1 \right] \times 8 \cdot 025 \sqrt{\frac{\gamma}{\gamma - 1} R T_2' \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma - 1}{\gamma}} - 1 \right]} \times A \times 60}{\frac{R T_2'}{P_2'} \times 33{,}000} \quad \ldots \quad (10)$$

The efficiency of the blower is equal to the theoretical horse-power required to compress the given volume of air

* Paper read before the American Society of Mechanical Engineers.

handled divided by the brake horse-power input at the shaft; hence, the efficiency of the blower is expressed by the equation

$$E = \frac{\text{air horse-power}}{\text{motor input} \times \text{motor efficiency}} \quad \ldots \quad \ldots \quad \ldots \; (11)$$

and the total overall combined efficiency will be

$$E_o = \frac{\text{air horse-power}}{\text{motor input}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \; (12)$$

in each of which the motor input has been reduced to horse-power.

The blower efficiency may also be found by the temperature-pressure method in any blower which is not water-jacketed, the procedure in this case being to calculate the theoretical temperature rise from the formula

$$T_1 - T_2 = T_2 \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma - 1}{\gamma}} - 1 \right] \quad \ldots \quad \ldots \quad \ldots \quad \ldots \; (13)$$

dividing it by the actual temperature rise found by sub-

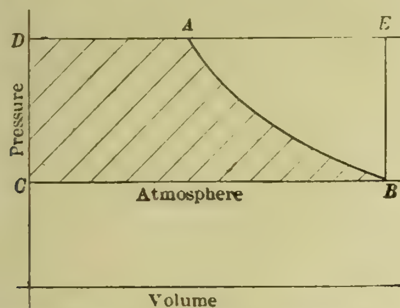


FIG. 19.—WORK DIAGRAM, SHOWING DIFFERENCE BETWEEN TEXT-BOOK AND CORRECTED FORMULÆ.

tracting the inlet temperature from the temperature in the blower discharge, which gives rise to the equation

$$E' = \frac{T_2 \left[\left(\frac{P_1}{P}\right)^{\frac{\gamma - 1}{\gamma}} - 1 \right]}{T_1' - T_2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \; (14)$$

Following is the derivation and use of formula (14).

To prove: The efficiency of a blower is measured by the formula

$$E' = \frac{T_1 - T_2}{T_1' - T_2}$$

where

- T_1 = theoretical final temperature of the air calculated from the adiabatic relation between pressure and temperature,
- T_2 = initial temperature of entering air,
- $T_1{}^1$ = final observed temperature in actual compressor.

Analysis. — Any losses of energy which occur in a blower must reappear in some other form, viz., as heat. Hence, the various losses of whatever nature occurring in a blower may be considered equal to x. The losses include friction, eddies, leaking, &c. Referring to Fig. 17, let AB be the theoretical adiabatic compression curve and HB the actual compression line. Let the section EG be an infinitely small lamina of height dp. Since the work of vdp must be $\frac{1}{1-x} vdp$ extending the area EG to a point F on an imaginary compression curve CD. Note that vdp is the work done on the air as shown by the area of the actual compression curve and not under the adiabatic. Since, from the fundamental assumption that energy lost is converted into heat, the first law of thermodynamics.

$$dQ = \frac{1}{\gamma - 1} vdp + \frac{\gamma}{\gamma - 1} pdv \quad \ldots \quad \ldots \quad \ldots \; (15)$$

may be used. Substituting for dQ its value, the area

$$GF = \frac{x}{1-x} vdp$$

equation (15) becomes

$$\frac{x}{1-x} vdp = \frac{1}{\gamma - 1} vdp + \frac{\gamma}{\gamma - 1} pdv \quad \ldots \quad \ldots \; (16)$$

Integrating equation (16) between p_2 and p_1 and v_2 and v_1

$$v_1 = v_2 \left(\frac{P_2}{P_1}\right)^{\frac{1 + \frac{x}{1-x} - \frac{x}{1-x}\gamma}{\gamma}} \quad \ldots \quad \ldots \quad \ldots \; (17)$$

$$\beta = \frac{1 + \frac{x}{1-x} - \frac{x}{1-x}\gamma}{\gamma} \quad \ldots \quad \ldots \quad \ldots \; (18)$$

Substituting the value of v found from equation (17) in the equation $dW = vdp$ and integrating,

$$W = \frac{RT_2}{(1-x)(1-\beta)} \left[\left(\frac{P_1}{P_2}\right)^{(1-\beta)} - 1 \right] \quad \ldots \quad \ldots \; (19)$$

Equation (19) gives the work done in foot-pounds per pound of air compressed from P_2 to P_1 including all losses of whatever nature occurring in the blower. It will therefore be evident that the efficiency of the blower will be equal to the theoretical work required to compress one pound of air from P_2 to P_1 divided by the actual work required for the same compression. Hence

$$E' = \frac{RT_2 \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} - 1 \right] \frac{\gamma}{\gamma - 1}}{RT_2 \left[\left(\frac{P_1}{P_2}\right)^{1-\beta} - 1 \right] \frac{1}{(1-x)(1-\beta)}} \quad \ldots \quad \ldots \; (20)$$

but

$$\frac{1}{(1-x)(1-\beta)} = \frac{\gamma}{\gamma - 1}$$

also

$$T'_1 - T_2 = T_2 \left[\left(\frac{P_1}{P_2}\right)^{1-\beta} - 1 \right]$$

hence the expression for the efficiency reduces to

$$E' = \frac{\frac{\gamma}{\gamma - 1} RT_2 \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} - 1 \right]}{\frac{\gamma}{\gamma - 1} RT_2 \left[\left(\frac{P_1}{P_2}\right)^{1-\beta} - 1 \right]} = \frac{T_1 - T_2}{T'_1 - T_2} \quad \ldots \quad \ldots \; (21)$$

At this point it will be well to take up the old formulæ

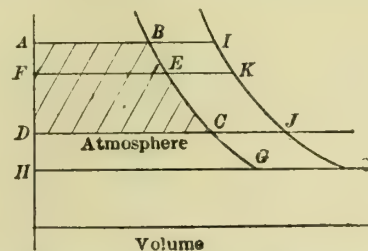


FIG. 20.—INDICATOR DIAGRAMS OF CENTRIFUGAL BLOWER FOR DIFFERENT CONDITIONS OF INLET TEMPERATURE AND PRESSURE.

used in a number of text-books dealing with the measurement of air, viz.,

$$V = \sqrt{2gh} = 8{\cdot}025\sqrt{h} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \; (22)$$

in which h is the head through which the medium flows. In the case of air, or any gaseous medium, h being taken as

$$h = \frac{P_1 D \times 13{\cdot}596}{12\rho} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \; (23)$$

in which

- P_1 = static, plus velocity head, in inches of mercury,
- D = weight of 1 cub. ft. of water at T'_2,
- ρ = weight of 1 cub. ft. of air at temperature T'_2 and barometric pressure.

Equation (23) is substantially correct for the measurement of velocity for comparatively low pressures, but gives a velocity slightly too high when employed for pressures of 2lbs. or 3lbs. or more, in which case the velocity, as previously pointed out, should be calculated from the formula (7) the error arising

from the use of formula (22) being shown in Fig. 19. The work done is represented by $2\,gh$, being the area $BCDE$, whereas the actual area is that under the adiabatic curve represented by the curve $BCDA$.

The method of correcting for temperature at inlet to blower, and for changes of barometer is as follows: The fundamental characteristic of the centrifugal blower is that for any given actual volume entering the blower inlet, the blower at a given speed will take a certain number of foot-pounds of work per pound of air, regardless of the intake temperature or pressure, and the result of this is that the ordinary methods of correcting for temperatures and barometer as applied to blowing engines, does not apply to centrifugal blowers. This will be seen from Fig. 20, which shows an indicator diagram of the centrifugal blower for different conditions of inlet temperature and pressure. Let the area $CDAB$ be the compression over the standard temperature and barometer, to some given pressure. This area will represent a fixed number of foot-pounds of work per pound of air. It is evident, therefore, that if the barometer readings were the same but the

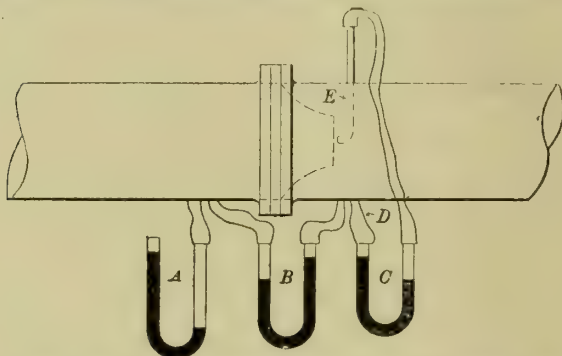


FIG. 21.—ARRANGEMENT OF TEST FOR DETERMINING FLOW IN PIPE.

intake temperature higher, *i.e.*, so that the initial volume were to point J instead of C, it is evident that the pressure to which the blower could compress would no longer be A, but some pressure F, such that the area $JDFK$ would equal the area $CDAB$.

Consequently, the correction for change of temperature from C to J would not be applied as affecting the actual volume entering the blower, but as a correction to the pressure. In the same way supposing that the barometer were low and the atmospheric line represented by HG at standard temperature, the area $GHFE$ must again equal the area $CDAB$, and consequently the pressure would be lower than it would be with the standard barometer. This is the correction for both inlet temperature and barometer, to the pressure of compression and not to the inlet volume. As previously stated, the work done in foot-pounds per pound of air remains constant; hence, having found the work in foot-pounds per pound of air over the actual test conditions, it is possible to substitute, in equation (4) the value of the standard inlet temperature in deg. Fah. absolute, and a standard barometer reading, and in this way to calculate the final pressure in the discharge for the standard conditions.

If P_2' and T_2' are the absolute pressure and temperature at the inlet to which the test results are to be corrected, it follows that the corrected discharge pressure P_1' will be given by the equation,

$$P_1' = P_2' \left\{ \frac{T_2}{T_2'} \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} - 1 \right] + 1 \right\}^{\frac{\gamma}{\gamma-1}}$$

which is the form to be used in all cases where the discharge pressure is to be corrected to constant conditions.

In Fig. 16, let AB represent the curve of pressure as determined from the original test data, and assume, for instance, that the temperature reading at the intake was higher than the standard, or that the barometer was lower than the standard, test points on the curves being represented by the crosses. The method of determining the pressure for standard conditions then would be to calculate the pressures on the line CD, as shown in Fig. 16, the curves being plotted, however, on the original volume lines.

When it is impossible to test a blower with the discharge going to the atmosphere, as when a nozzle is used as shown in Fig. 8, the discharge may be measured by obtaining the velocity in the discharge pipe by means of a pitot tube. These measurements are not always reliable, however, as ordinarily made, since great difficulty is experienced in obtaining the true static pressure of a moving fluid, for the reason that the "pressure end" of the tube itself disturbs the stream lines, and hence inaccurate readings are probable.

If a pitot tube is used in the ordinary way the pressure end should consist of a thin plate about 4in. long by about 2in. wide, having a slit about $\frac{1}{32}$in. wide and 2in. long at its centre. A collecting chamber back of the slit connected to the search pipe tends to equalise the pressure and give a true static pressure reading; but great care is necessary to see that the flat plate is exactly parallel to the stream lines at the point the pressure is desired.

A method of determining the flow in pipes which the writer believes is far more accurate and reliable than ordinary pitot tube readings is shown in Fig. 21. A well-rounded nozzle having an area of one-fourth to three-fourths that of the pipe is bolted in between two flanges. On the high-pressure side of the nozzle there is a gauge A and a thermometer (not shown), and a second gauge B has one leg connected to the high-pressure side of the nozzle and the other to the low-pressure side, thus giving the drop of pressure through the nozzle. A pitot search tube is fitted on the low-pressure side of the nozzle as shown in the figure. This search tube has its opening pointed directly against the flow through the nozzle, and should have a graduated scale so that its position in front of the nozzle can be accurately known. The advantages of this arrangement are that the difficulty of obtaining a true pressure reading is avoided, and a number of checks may be made on the readings taken, so that should inaccuracies occur for any reason, they can be immediately detected and the trouble located.

From Bernouilli's theorem, the sum of the pressure head and velocity head must always be equal, hence with the search tube E in the position shown in Fig. 21, the pressure differences shown by gauges B and C must be equal. Also, if the connection D to gauge C be disconnected, the pressure indicated by gauge C must equal the pressure shown by gauge A. Also, if gauge C is connected to the pipe by D, but the pitot tube disconnected, the sum of gauges B and C must equal the pressure indicated by gauge A. If these various readings check, it follows that the static pressures are being accurately measured and that the pitot tube is pointing directly into the stream.

Having thus checked the correctness of the measurements, the jet can be searched by moving the pitot tube across the nozzle at regular intervals, and readings taken, from which the velocity at any point can be calculated by the formula

$$V = \sqrt{2g\,\frac{\gamma}{\gamma-1}\,RT_1\left[1-\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right]}$$

where

P_1 is the absolute pressure above the nozzle,
P_2 is the absolute pressure below the nozzle,
T_1 is the observed temperature above the nozzle,
V is the velocity in feet per second.

With V known and a known area of discharge, the volume passing can be calculated. By this method if the observations are carefully made, the error should not exceed a very small fraction of 1 per cent. It may not be out of place to add that too great care cannot be taken to make sure that there are no air leaks in the connections to the gauges, as even a pinhole may cause a very considerable error in the readings.

In the following, in order to show the method of working up a test on a centrifugal blower, the actual readings taken during a one-hour test on a 30,000 cub. ft. blower have been used. The results have been worked out by seven-place logarithms, using the formulæ as given under tests. For practical purposes, however, it is rather inconvenient to work out the values of

$$\left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} - 1$$

and

$$\left\{ \frac{T_2}{T_2'} \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} - 1 \right] + 1 \right\}^{\frac{\gamma}{\gamma-1}}$$

by logarithms, and therefore the writer has prepared a set of curves for the value of

$$\left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} - 1 = K$$

for various values of $\frac{P_1}{P_2}$, which may also be used for the solution of the equation for the pressure correction.

APPENDIX.

TEST ON WESTINGHOUSE TURBINE BLOWER.

Nozzle: $12\frac{1}{4}$in.

Static head: $P_1 = 85.6$in. water + 26·66in. mercury = 32·96in. mercury.

Barometer $P_2 = 26.66$in. mercury.

Intake temperature: $t_2 = 46.8°$ Fah.: $T_2 = 507.5°$ Fah. abs.

Discharge temperature: $t_1 = 92.6°$ Fah.; $T_1 = 553.3°$ Fah. abs.

Total input to motor = 432·7 kw.

input to exciter = 4·04 kw.

input motor only = 428·66 kw.

Efficiency motor = 89·6 per cent. taken from curve including windage.

Area of nozzle = 0·817 sq. ft.

$$\left\{ \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} - 1 \right\} = 0.06317$$

W = work in ft.-lb. per lb. of air

$$= 184.754 \times T_2 \times \left\{ \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} - 1 \right\} = 5923$$

T'_2 is the absolute temperature at outlet of nozzle

Volume per minute in cubic feet at temperature T'_2 = Vol. T'_2

$$\text{Vol. } T_2' = 109.079 \sqrt{T_1 \left[1 - \frac{1}{\left\{ \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} - 1 \right\} + 1} \right]}$$

Area × 60 = 30,659 cub. ft.

$$\text{Vol.}_{60} = \frac{\text{Vol. } T'_2 \times 520.7}{T_1} \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} = 30{,}670$$

V_{60F} = Vol. of 1lb. of air at 60° Fah. and barometer

$$\text{Air h.p.} = \frac{\text{Vol. }_{60°}}{V_{60F}} \times \frac{W}{33{,}000} = 373.99$$

To find V_{60}: $pv = RT$ p in lb. sq. ft. = barometer

$$V_{60} = \frac{53.35 \times 520.7}{\text{Bar.}}$$

Barometer = 26·66in. mercury = 1,887lbs. sq. ft.

Efficiency derived from temperatures:

$$E' = \frac{T_2 \left[\left(\frac{P}{P_2}\right)^{\frac{\gamma-1}{\gamma}} - 1 \right]}{T_1' - T_2} = 69.997 \text{ per cent.}$$

$$T_1 = 553.3$$
$$T_2 = 507.5$$

Efficiency derived from motor input:

Air h.p. = 373·99 Input to motor only = 428·66 kw.

Input to motor and exciter = 432·70 kw.

$$\text{Overall} = \frac{\text{air h.p.}}{\text{total input to motor in h.p.}} = 64.179 \text{ per cent.}$$

$$\text{Blower} = \frac{\text{air h.p.}}{(\text{motor input} - \text{exciter input}) \times \text{motor in h.p.}}$$

= 72·641 per cent.

$$P'_1 = 26.7 \left[\frac{T_2 \left[\left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} - 1 \right]}{520.7} + 1 \right]^{\frac{\gamma}{\gamma-1}} = 32.837\text{in. mercury}$$

$P'_1 - P'_2 = 32{,}837 - 26.7 = 6.137$in mercury

= 48·23 ounces per sq. in. corrected to 26·7in. barometer and 60° Fah. at the inlet.

THE POURING TEMPERATURE OF MANGANESE-BRONZE.*

BY H. W. GILLETT.

THE method of making a manganese bronze test bar and the form of the bar has a great influence on the apparent strength. The most noticeable point in manganese bars is that while a poor grade of bronze may show a clean, fine-grained fracture and a low strength a good grade of bronze only has low strength when the fracture shows yellow or lemon-coloured spots. Just what these spots are we do not yet know, but their cause is evident, since they appear only when a test bar has not been properly fed, and no matter how perfect the fracture of an ingot, bars made from it, without due attention to feeding, will always show these yellow spots.

Besides the questions of the form of the bar and the method of making it, it has seemed to us that another variable should be taken into account, and that is the temperature of pouring, since the casting temperature and consequent rate of freezing may greatly affect the feeding and the grain, or size of the crystals. To test this, we made some experiments with a manganese bronze of which the following is a typical analysis: Copper, 56·00; tin, 0·90; aluminium, 0·45. This corresponds well with the specifications of the American Society for Testing Materials. The tin is, of course, lower than the 2 per cent. allowed as a maximum by these specifications. This organisation specifies a tensile strength of 70,000lbs. per square inch and an elongation of 20 per cent. on standard test bars $\frac{1}{2}$in. diam. and 2in. in breaking section cut from the bottom of the ingot. This is a very fair specification and one easy to meet.

Instead of going to the expense of cutting and machining a bar from the ingot, we cast test bars made to size from each heat, at the same time that the ingot moulds are filled. These are pulled without machining, and serve admirably for rapid routine control. The bars are $\frac{1}{2}$in. diam. and 2in. long in the breaking section, which is joined by a liberal fillet to the grips, which are $1\frac{1}{4}$in. long and $\frac{7}{8}$in. diam. These bars are made with very heavy gates and risers to ensure good feeding. However, they usually show very tiny traces of yellow spots, and give a tensile strength slightly, and an elongation considerably, below that of bars cut from the ingot or cast in a small chill mould.

We have also made bars from the brick pattern, some modification of which is, we believe, accepted as the best pattern for manganese test bars. This consists of a block 2in. high, 4in. wide, and 9in. long, carrying a keel 1in. by $1\frac{1}{4}$in. by 9in. The keel is cut off and the bars machined to standard A. S. T. M. size from it.

As a matter of curiosity we have also cast an ingot in a copper mould about 1in. by 1in. by 12in., from which ingot the standard bar is machined. Following usual foundry practice as to temperature of casting the results on these different forms of bars are as follows:—

	Tensile strength. pounds per square inch.			Elongation per cent.		
	Min.	Max.	Average.	Min.	Max.	Aver.
Cast to size	75,000	85,000	79,000	15	20	16
Brick pattern ..	77,000	85,000	82,000	20	35	25
Chill mould	86,000	88,000	87,000	18	25	23

We took a heat of an ingot which had given in the cast-to-size bar the following results, the pouring temperature not being taken:—

Remarks.	Tensile. strength.	Elastic limit.	Reduction of area, per cent.	Elongation per cent.
Trace of yellow at fracture	80,000	45,000	15	15
Trace of yellow at fracture	79,000	44,000	18·5	17

On remelting the ingot, the tensile strength is slightly lowered and the elongation considerably increased. This was melted and poured at the temperatures given in Table I., into

* Paper read before the American Institute of Metals.

both cast-to-size and brick pattern bars. The metal was allowed to cool between casts without stirring or cooling by gates or other metal.

The elastic limits are probably accurate within about 2,000lbs. We do not consider the elastic limit or reduction of area of much use in evaluating manganese bronze, as the ultimate strength and elongation give more accurate figures and quite adequate data as to strength and ductility. The elastic limit runs so closely from 50 to 60 per cent. of the ultimate strength that the latter test will serve all purposes.

The results are not just what we might expect. In general, the tensile strength of an alloy increases with decreasing pouring temperature, which gives quicker freezing and hence smaller crystals and a closer grain. In tests on some 40 alloys of aluminium with copper, with zinc, and with both copper and zinc in various amounts, we have found that, roughly speaking, an alloy poured at 1,500° Fah. will not have over 90 per cent. of the tensile strength of one poured at 1,300° Fah. This theory is upheld by the comparison of the bars poured at 2,125° cast-to-size and in the brick pattern, where the bars cast-to-size were practically free from the deadly yellow spots, and thus showed that the feeding was pretty good. In this case, the bars cast-to-size gave the higher tensile strength, due probably to the quicker chilling of the small bulk of metal compared to the large bulk in the brick pattern.

TABLE I.

RESULTS ON REMELTED INGOT.

Bars Cast to Size.

Pouring temperature. Degs. Fah.	Tensile strength.	Elastic limit.	Reduction of area. per cent.	Elongation. per cent.	Remarks.
2,125	79,000	38,000	28·5	28	tiny trace of yellow.
2,125	78,600	39,500	21	25	tiny trace of yellow.
2,000	76,500	42,600	18·8	17	trace of yellow.
2,000	75,600	43,000	20·7	18	trace of yellow.
1,900	75,200	42,000	22·9	18	a little yellow.
1,900	71,800	43,000	16·5	13	quite a little yellow.
1,825	68,300	40,000	18·2	14	large yellow spot at centre.
1,825	65,100	39,500	19·8	11	large yellow spot at centre.
Brick Pattern.					
2,125	77,300	41,000	31·8	35	no yellow; fine grain
2,000	76,900	41,500	34·1	34	no yellow; fine grain
1,900	76,500	41,100	30·5	30	no yellow; grain slightly coarser.
1,825	76,000	41,700	19·7	24	no yellow; grain much coarser.

On the other hand, in the brick bars poured at different temperatures, although none showed yellow spots, those cast hottest were the best, and those cast coldest showed the coarsest grain. In the bars cast-to-size there was no perceptible difference in the grain between those poured hottest and coldest. In the bars cast-to-size, it is very noticeable that the yellow spots increased and the strength decreased as the pouring temperature was lowered. That is, freezing was too rapid for proper feeding.

Evidently, then, we have two factors to consider, speed of chilling and feeding. In bars cast-to-size, the chilling is rapid, but not rapid enough to prevent the segregation of whatever the yellow spots consist of. Hence the feeding is the overwhelming variable, and the hotter the bars are poured the better the feeding. In the brick pattern, the bulk of metal is so great that the chilling effect is not very great and the form is such that proper feeding is automatic and inevitable. This pattern is the most fool-proof, and will give a very good idea of the value of the manganese. It does not give the fictitious strength of a chill cast bar, and comes more closely to showing what the ingot will do in properly fed castings than any other form. Change in pouring temperature has comparatively little effect on brick pattern bars. The elongation is affected more, though not as much as in those cast-to-size.

The best pouring temperature for test bars appears to be from 2,000° to 2,100° Fah. It should not be forgotten, however, in making castings, that heating to a too high temperature will burn out some zinc, increasing the ductility and decreasing the elongation, and increasing the danger of blows and similar foundry defects. We should, therefore, say that the best pouring temperature for average castings would be from 1,950° to 2,000° Fah., though the questions of shrinkage or possibility of misruns on very heavy or very light castings might alter the best temperature for particular patterns.

THE LAW OF PLASTIC FLOW OF A DUCTILE MATERIAL AND THE PHENOMENA OF ELASTIC AND PLASTIC STRAINS.

A PAPER on this subject was read by Mr. C. E. Larard at a recent meeting of the Physical Society. The author gave an account of the twisting to destruction at a uniform angular velocity of a cylindrical steel specimen 3in. diam. and of his deductions from the experimental data. The following deductions were made: (1) The rate of increase of the torque with the time varies inversely as the time. (2) The acceleration of the torque velocity which is negative or, as it may be called, the de-celeration, varies therefore inversely as the square of the time. (3) The variables, time t, and torque T, are connected by the compound interest law. More exactly $t+t_o=a\epsilon^{bT}$, where t_o is a time constant. Corresponding results in terms of the angle of torsion θ and T obviously followed, since $\theta=\omega t$, where ω is the angular rate of straining. The author next proceeded to summarise certain other conclusions he has formed as a result of many experiments extending over five years, illustrating his arguments by means of original diagrams, but reserving the full account for later publication.

(1) The Elastic Period.—(a) Plastic strain is always produced by applied stress, and when its amount becomes large enough to be detected by the strain instrument the actual linearity between stress and strain is no longer directly obvious. (b) The recorded limit of elasticity depends on the degree of accuracy to which the strain instrument is capable of indicating the strain, *i.e.*, there is no definite limit of elasticity, the recorded limit being merely an instrument limit. (c) In the case of a tension test where the increase of strain is measured in the direction of the applied stress linearity between stress and strain is apparently very pronounced, but in the case of a torsion test very small increases in the elongation of helically twisted generating lines of the specimen are accompanied by the relatively large angles of torsion measured by the twist-strain instrument, with the result that plastic strain is observed very early in the test giving low instrument limits of elasticity. (d) There is elastic strain whether it is obscured by plastic flow or not, which is closely proportional to the torque (or load) for all values of the torque (or load) up to the maximum, and it is given by $\theta_t/T=\theta_1/T_1$, where T is any torque not exceeding the maximum load, and T_1 and θ_1 are any observations of torque and twist respectively during the elastic period of instrumental linearity between stress and strain. Consequently the usual formula may be used for calculating elastic strains, provided the torque is not greater than the maximum. (e) The total strains produced under applied stress even before the yield period is reached depend on the time as well as on the torque (or load). (f) The linearity between strain and applied stress may be rendered obvious up to a high value of the load by suppressing the plastic flow.

(2) The Yield Period.—(a) The plastic strain phenomena under constant load during this period depends on the time. If the load is imposed on a specimen either very slowly or very quickly there is no yield period, the former case corresponding very closely to isothermal straining and the latter to adiabatic. (b) When the yield torque (or load) is reached and where equilibrium is maintained between the load and the resistance the velocity of the plastic strain is rapidly and increasingly accelerated for a short period of time due to some rapidly and increasingly softening process going on in the material, the acceleration θ rapidly reaching a maximum value followed for a short period by a rapidly decreasing acceleration, the velocity θ still increasing until the acceleration reaches zero value with momentary uniform velocity.

From this point and for by far the greater part of the yield, the velocity θ undergoes constantly decreasing retardation (due to some gradual and increasingly hardening process going on in the material) until the curve in θ and t becomes, or tends to become, asymptotic to the axis of time with a uniform value of θ. (*c*) From what has been stated above it follows that the yield period is produced when from the conditions of loading acceleration of plastic flow is produced, and, further, that where the torque-time and torque-twist ratios are kept below certain critical values, and, therefore, where there is no acceleration but only a retardation no yield period is produced and the elastic-torque-twist line and the plastic-torque-twist curves are compounded into a smooth and continuous resultant torque-twist diagram. (*d*) The yield period is due to the production of a fluid state (liquefaction) in parts of the material under the acceleration with subsequent relegation and hardening, producing de-celeration after the parts have adjusted themselves to their new positions. The torque-twist curve, which is continuous, denotes a condition of semi-plastic flow. (*e*) The yield period which takes place under the circumstances indicated can be raised by strain and heat treatment at low temperatures to almost any position with respect to the torque-twist curve.

(3) Total Strain.—If the above results are accepted the total strain is the sum of the elastic and plastic strains, where the elastic strain is a linear function of the load for all ordinary speeds of loading and where the plastic strain is function of both load and time.

MINING PROBLEMS.

DR. CADMAN, Professor of Mining in the University of Birmingham, delivered his presidential address to the members of the South Staffordshire and Warwickshire Institute of Mining, at the University on Monday last. The time-honoured custom of presidents, he said, was to review generally the progress of the science in mining during the past year. He did not propose to follow it, but to preface a short paper on a subject of considerable importance at the present moment with a few general remarks. He had deliberately adopted that course. His thoughts had been drawn to accidents in mines and to legislation, and at the outset he felt inclined to venture upon a reflection of the possible effects for good or evil that might be the outcome of the new Mines Bill—the apparent nightmare of every colliery manager of to-day. Shortly after the passing of the Mines Bill of 1892 the president of the institute pointed out its severity, and the almost impossible conditions it contained. Such a state of mind existed amongst many of them at the present moment with regard to the 1911 Act. As he was inclined to think history would repeat itself, and in due course they would view the legislation in a different light, he had refrained from addressing them on the topic.

To all students of the Act, however, one potent feature was clearly brought to light, viz., that the responsibilities of the manager had been enormously increased, and in order to shoulder that responsibility the colliery manager of the future must possess more than a smattering of science. The school of bitter experience could not entirely train him to fulfil the duties he was to be called upon to discharge. It had been stated that a "mine manager like a master mariner is made only by a long and often painful practical apprenticeship, and that the University life of freedom makes a serious inroad on the unrelenting force of discipline which is essential for every man responsible for the lives of his subordinates," and that "the mine manager should be trained in the mine, supplemented by evening classes." Such a statement emanating from an authority responsible for the conduct of mining education in a sister University, referring as it did to the training of mine managers of the future, could not be too strongly refuted. It was directly opposed to the principles which the institute had laid down. That institution was largely responsible and instrumental in formulating the Department of Mining which it was his privilege to control, and he would be betraying their confidence if he did not in the strongest terms possible condemn such a policy. As an institution they had always urged the necessity of opportunity being afforded young men entering their profession to obtain a University training in the general principles underlying the science of mining. They had forcibly demonstrated that the higher training, both practical and theoretical, was indispensable to the welfare of their profession. They had shown by their active co-operation with county council evening classes that both the University and the classes were requisite for the complete scheme of mining education. They had shown that all classes of mine officials required technical training, and what was sufficient for subordinate officials was not enough for the captains of their great industry. It was not generally understood outside the district how fully the general scheme of mining education had developed in their immediate midst, and how fully that district had recognised it should be such as to afford a training for the duties of life; and further, how the different types of education were designed for leaders and subordinates. The younger men, who by lack of enthusiasm were not taking advantage of the opportunities offered to them, he warned to beware of those who were actively following the course the institute had so much at heart, and would be waiting to pounce upon their infirmities and to displace them in the future fight for existence

Dr. Cadman went on to allude to a growing requirement to which all colliery engineers must, in his opinion, sooner or later turn their attention, namely, the production of a smokeless fuel for household and manufacturing purposes, with the conversion of the volatile products into liquid fuel. Those two problems were confronting them at the moment. Liquid fuel was required for modern engineering developments. The internal-combustion engine already pointed to the relegation of the steam boiler to the museum, whilst social development pointed its finger at the volumes of solid matter and wasted energy belching forth from every chimney, whether factory or dwelling. At the same time, mining engineers were realising that in order to produce a revenue which would permit the colliery to exist, it was necessary to place a price upon the fuel in its crude state which was beyond its real value. Indeed, through modern legislation and social development and increased difficulties in mining, so fine had become the balance of working cost to selling price in some districts, that unless a new field of application were developed which would move the balance in a more favourable direction, an unfortunate collapse was inevitable. The public outcry for liquid fuel and the reformers' movement for smoke abatement, suggested the application of a process by which coal might be treated at the mine so as to produce a suitable fuel which would burn freely and without smoke, and would turn out a residue of liquid fuel from which oil of various characteristics might be fractionated, at the same time permitting great economy in the colliery power consumption. Already much good research had been accomplished in that direction, and it was not unreasonable to expect that a process would be evolved, if it were not already with them, that would permit the carbonising of coal under conditions of low temperature which would convert a crude fuel barely being worked at a profit into products which the civilised world was about to demand, and at the same time retaining to the coal-mining industry lucrative investment for British capital.

West of Scotland Iron and Steel Institute.—At a meeting of the West of Scotland Iron and Steel Institute, held on the 13th inst. at Glasgow, Prof. E. G. Coker, D.Sc., of the Finsbury Technical College, London, delivered a lecture on "Colour Photography of Internal Stress in Bodies of Engineering Form." Mr. Walter Dixon, the president, occupied the chair.

Solid Vulcanite Rollers for Roller Bearings.—In a patent recently granted to Mr. E. Jones, and Messrs. Kynoch, Ltd., Lion Works, Witton, Birmingham, it is proposed to use solid cylindrical rollers, cut from round rods of vulcanite, or similar material, the rollers being kept in an axial position with relation to the shaft by means of a cage formed with slots in which the rollers revolve. The use of rollers of this material will not, it is claimed, injure the journal of the shaft which is rotating in the bearing, nor the bearing itself in which the rollers work, but will reduce to a minimum the wear of the journal and bearing, so that when the rollers have worn they may be replaced by new rollers of the original dimensions, and which, without any other modification, will render the roller bearing equal in all respects to a new one.

INDUSTRIAL AND TRADE NOTES.

Messrs. T. Sugden, Ltd.—The directors of this company have declared a dividend at the rate of 15 per cent. per annum, which is the same as in the previous year.

New Canadian Pacific Railway Liners.—The Canadian Pacific Railway Company has, we learn, placed orders with Messrs. Barclay, Curle, & Co., Whiteinch, for two ships of 12,000 tons each, with a speed of 16 knots, to replace the "Lake Champlain" and "Lake Manitoba."

Trade Circulars and Catalogues.—Richardson, Westgarth, & Co., Ltd., Hartlepool, have issued a pamphlet illustrated with coloured diagrams which show in a clear way their "contraflo" system of utilising steam for power and auxiliary purposes. The Greenwich Metal Works, Woolwich Road, London, send us an illustrated booklet of their numerous patterns of perforated sheet-metal.

Castolin.—Messrs. Wassermann, Lieber, & Co., of Lausanne, Switzerland, have appointed The Castolin Company, of Clock House, Arundel Street, Strand, London, W.C., as their sole general agents for the United Kingdom for the sale of their "Castolin" compounds for the autochemical welding of cast iron, cast steel, tool steel, high-speed steel, &c., without plant.

Messrs. W. F. Stanley & Co., Ltd., of Great Turnstile, Holborn, W.C., the well-known manufacturers of surveying, drawing, and scientific instruments, have, owing to the continued expansion of their business, been compelled to provide much larger office accommodation, and have now taken over the whole of the upper part of the premises at 286, High Holborn, where their showrooms have been on the ground floor for some time. Their old premises at 4 and 5, Great Turnstile, are being retained for export business only.

New Birmingham Electric Supply Station.—The Birmingham Electric Supply Committee had under consideration recently the proposal to erect a new electric supply station at Nechells, the ultimate cost of which, it is estimated, may reach a million pounds. It was decided to ask the council for sanction to proceed with part of the scheme at once. When completed the station will be one of the largest generating stations in the country. The portion to be provided first will cost some £250,000 for building and equipment.

Shipbuilding at Belfast.—Returns just issued of Belfast shipbuilding for the year 1912 show an aggregate of over 162,600 tons. Of this amount Messrs. Workman, Clark, & Co. launched 9 steamers and an Admiralty caisson, totalling 85,000 tons, as compared with 66,000 last year; while Messrs. Harland & Wolff put off seven vessels, totalling 77,000 tons, as compared with 118,000 tons, including the "Titanic" in 1911. Messrs. Workman, Clark's largest boat was the Holt liner "Nestor," and the Queen's Island Yard's largest was the White Star liner "Ceramic."

Launch of a White Star Liner.—A new passenger liner for the White Star Company's Australian service—the "Ceramic"—was launched on the 11th inst. from the yard of Messrs. Harland and Wolff, Ltd., Belfast. The steamer, which far surpasses in size anything hitherto placed on the Australian berth, measures 675ft. in length by 69ft. 3in. in breadth, and will have a gross tonnage of about 18,000 tons. The vessel is a triple-screw steamer, and will be fitted with twin-screw reciprocating engines combined with a low-pressure turbine. It is anticipated the "Ceramic" will be in commission about next midsummer.

French Motor Industry.—According to a recent American Consular report, France leads the world in the exportation of automobiles. For the first six months of 1912 the total French exports of motor-cars amounted to about £4,000,000, an increase of 25 per cent. as compared with the exports for the same period of 1911. The importation of automobiles into France for the same six months amounted to an estimated value of £250,000, a slight increase of less than £1,000 over the same period of the previous year. The progress and development of the manufacture of automobiles has placed it among the nation's most important industries.

Steam Turbines to Replace Reciprocating Sets at Greenwich.—The large low-speed steam engines of the vertical-horizontal reciprocating type which were installed some 6½ years ago in the Greenwich tramways generating station of the London County Council are, according to a report recently issued by the Highways Committee, to be replaced by two 8,000 kw. turbines. These units will go in the space occupied by two of the 3,500 kw. reciprocating plants, thus showing a clear gain of 9,000 kw. in generating capacity, while, further, it is estimated that an annual saving of nearly £16,000 will result, with coal at its present price, and with the present maximum output. At a later stage the remaining engines will be replaced by two similar turbine units, and the normal capacity of the Council's Greenwich plant will then be 52,000 kw.

Riveters' Piece Rates.—A conference of shipbuilding employers and men was held on the 12th inst. at Edinburgh. The meeting was between representatives of the Shipbuilding Employers' Federation and the Boilermakers' Society, and the principal subject of discussion was the rates of pay of riveting squads. As is well known, the members of the Boilermakers' Society voted recently in favour of ceasing to work piecework until the employers granted a 4 per cent. advance to riveters, so that the riveters, in their turn, might be able to give the holders on 10½d. per 1s.—instead of 9d., as at present. The vote, however, was a very small one, and instead of acting on it immediately the Executive Council of the society asked for a conference with the employers. It is understood that the employers, in view of their previous decisions on this question, declined to re-open it. Several local disputes were also considered, especially the series of disputes which have taken place recently in different districts, in connection with which there have been a number of sectional stoppages of work. In regard to these stoppages the conference accomplished some practical and effective work.

Duties of Consuls to British Trade.—At the annual dinner in connection with the Institute of Commerce recently held in Birmingham, the Chairman, Mr. Hugh Miller, of Glasgow, in referring to the duties of our consuls and vice-consuls in towns or cities abroad, said they were supposed to protect British commerce and its interests, but they were appointed, not because they were business men, not because of the possible benefit they could do to British trade, but because of family or political connections. Now they could not blind their eyes to the fact that, if appointments were made in this way, it started the man himself off on quite a wrong course of action, or perhaps inaction, and without a proper idea of the work. Whereas if the British Government took care that the first work of a consul was to keep their manufacturers and merchants informed in foreign trade conditions and the reasons why they were losing ground in certain markets, and to inform the home people of all the most up-to-date methods in commercial life that were being tried by other Governments, in how much better position would the British commercial men be placed. It seemed to him that the Institute in coming years could do useful work in this direction.

Boilermakers and a National Agreement.—The December report of the Boilermakers' Society contains the result of the voting regarding the proposal that the union should have a working agreement on their own account—apart from the other trades—with the Shipbuilding Employers' Federation. The question was submitted to the members by the "National Assembly," which met at Newcastle on September 10th and 11th, and it was put before them in the following form: "That we favour a National Agreement between the Shipbuilding Employers' Federation and the United Society of Boilermakers and Iron and Steel Shipbuilders for dealing with general fluctuations of wages and questions of an agreed general character or such as may be remitted from local conferences with the consent of both parties at local conference. All local questions to be dealt with locally and finally in localities There shall be a neutral chairman at all local conferences." The result of the vote was as follows: For, 3,691; against, 1,328; majority for, 2,363. The total membership of the society at the end of November was 60,500, so that the number who voted—5,019—was only a twelfth of the total. The executive council will take steps to give effect to the vote.

Work in Australian Factories.—Information in regard to manufacturing industries of Australia has been received from Mr. G. H. Knibbs, Commonwealth Statistician. These returns show that the number of factories increased during 1911 by 603, or 4·35 per cent., while the increase in the number of persons employed was 24,809, representing a percentage increase of 8·65. The salaries and wages, which in 1910 were £23,870,510, totalled £27,551,876 in 1911, an advance of 15·34 per cent. The value of materials used during 1911 was £79,076,576, as compared with £72,796,236 the previous year, and the total output of the factories rose from £120,860,158 to £133,136,560. The capital invested in land, buildings, plant, and machinery was £64,098,144 in 1911, being an advance on 1910 of £6,608,670. The proportion that each of the items of outlay bore to the value of output is of interest. Wages, fuel and materials used absorbed 20·68, 2·07, and 5·39 per cent. respectively, leaving 17·86 per cent. to cover rent, maintenance charges, depreciation, interest on capital employed, insurance of all kinds, bad debts, &c., and profit. The average amount of wages paid per employé in the Commonwealth factories was £87 in 1910, and £92. 5s. in 1911, an advance of nearly 6 per cent. during last year.

South Wales Tinplate Trade.—The practical extinction this year of the South Wales tinplate exports to the United States and the heavy drop in the exports to Canada were referred to recently by Mr. H. C. Bond, a member of one of the largest tinplate firms in the country. Mr. Bond said there was occasion for great anxiety, as the production of tinplates in the United States, and more so in Germany, had grown faster than the demand. The estimated production in the United Kingdom this year was about 75,000 tons. In 1911 the United States produced 785,000 tons, and it was believed that the production this year would be increased to 900,000 tons. Twelve years ago the United States was the mainstay of the Welsh tinplate industry, but to-day the market had absolutely dwindled to nothing, and it would not stop there. They would inevitably lose the Canadian market unless they could have the same preference on tinplates as on galvanised iron. The exports to Germany were going to fall off considerably, and he had no doubt that in a few years' time the German market would disappear for the use of tinplates, like the Canadian market. To-day steel works were being hurriedly constructed in South Wales, and the inevitable result would be that when steel was imported those works would be idle and the cost of production raised.

Brass Trade "Pools."—Considerable progress has, we understand, been made with the scheme for forming "pooling" associations in two sections of the brass trade, with the view of restricting competition and eliminating reckless price-cutting. The two sections of the industry refer to those engaged in the production of water, steam, and beer fittings, and the gas-fittings branch. Pooling schemes are designed to regulate production and prices. Members of the "pool" are allotted a certain production based upon their average output over a period of years, and if they exceed that production they pay certain penalties into a fund, from which compensation is paid out to those firms whose output falls short of their allotted proportions. The form of combination proposed in the water and gas-fittings sections of the brass trade will be on these lines, though no decision has yet been arrived at concerning the payment of rebates. Moreover, the promoters declare that it is not their intention to use the proposed organisation for the purpose of establishing high prices. Committees have been formed to carry on negotiations with the manufacturers in the trade, and we understand that the support forthcoming is satisfactory. Several firms have already made their financial deposits and sent in their returns.

Employment in the Engineering Trades.—The report of the Labour Department of the Board of Trade states that employment improved in November, especially in the shipbuilding trades. The percentage of trade union members unemployed was the lowest recorded during the past 10 years. The upward movement in wages continued. Compared with a year ago, all the principal industries showed an improvement, which was most marked in the pig iron, iron and steel, and engineering trades. The changes in the rates of wages taking effect in November were, with one exception, all increases, and resulted in a net increase of £17,400 per week in the wages of 347,000 workpeople. The most important changes affected 305,000 coal miners in Northumberland, Durham, and Scotland, 3,500 blastfurnacemen in West Scotland, 3,130 steel-melters, &c., in various parts of England and Scotland, and 20,000 engineers in Manchester. The number of disputes beginning in November was 67, and the total number of workpeople involved in all disputes in progress during the month was 32,289, compared with 36,312 in October, and 37,076 in November, 1911. The estimated number of working days lost by disputes during the month was 297,400, as compared with 301,000 in the previous month, and 409,500 in the corresponding month of last year.

The "Lightning" File.—Manufacturers in Sheffield are displaying marked activity and enterprise in producing files of high efficiency, and to an increasing extent users are buying such goods on the basis of the amount of work they do under mechanical tests instead of merely accepting the lowest tender. American competition in this important industry was practically eliminated from the home market several years ago, and Sheffield makers have gone well ahead of their Transatlantic rivals in developing what is known as the "high speed" file. We have before us the report of a test by the Sheffield Testing Works, Ltd., of the high-speed "Lightning" file which has lately been placed on the market by Messrs. Lockwood Bros., Ltd., of Spital Hill, Sheffield. According to this report a 14in. file, tested on both sides, made 120,000 strokes, and in 39 hours removed 78·80in. of metal, weighing 22lbs., from an inch square bar, and at the conclusion of this severe trial the tool was reported to be "slightly worn." The makers claim the result of the test to represent the highest point of working efficiency ever attained by a file under similar conditions. It may be of interest to state that the Admiralty require the files they buy to make only 20,000 strokes and to remove 6in. of material. In round figures the "Lightning" file is capable of doing treble the amount of work that can be got out of an ordinary file, and as the increased price is inconsiderable, it must be highly economical in use.

Finances of Trade Unions.—The current number of the "Board of Trade Labour Gazette" contains statistics dealing with the membership, income, expenditure, and funds in 1911 of 100 of the principal trade unions. These unions, with an average membership of about 18,000, accounted for 60 per cent. of the total membership of all unions, the remaining 40 per cent. being distributed among 1,072 unions, with an average membership of a little over 1,000. The membership at the end of the year was 1,816,506, and the income amounted to £2,936,754, an average of 32s. 4d. per member. The expenditure was £2,502,217, an average of 27s. 6½d. per member; whilst the total funds amounted to £5,570,690, an average of 61s. 4d. per member. These figures compared with 1910 as follow: Membership 1,469,320, income £2,704,166, an average of 36s. 9d.; expenditure £2,631,930, an average of 35s. 10½d.; the total funds amounting to £5,136,153, an average of 69s. 11d. Owing largely to the general increase in membership which occurred in 1911, the total income for that year was the highest recorded. From the same cause, however, the amount of income per member, as well as the amounts per member of expenditure and of accumulated funds, was lower than in any other of the preceding 10 years. The total amount of funds showed a large increase compared with 1910, and with the exception of 1907 was the highest on record. During the 10 years 1902-1911, £22,946,000 was spent by the 100 principal unions. Of this amount £2,455,000 (or 10·7 per cent. of the total) was spent in dispute pay, £6,140,000 (or 26·8 per cent.) on unemployed benefit, and £9,543,000 (or 41·6 per cent.) on sick and accident, superannuation, and other benefits and grants, while the remaining £4,808,000 (or 20·9 per cent.) was absorbed by working expenses and miscellaneous expenditure. Exceptionally large amounts of dispute benefit were paid in 1911 by unions in the printing, transport, and textile trades; while, on the other hand, there was a considerable reduction in the expenditure under this heading by unions in the metal, engineering, and shipbuilding trades, and by unions in the mining and quarrying industry.

The Institution of Civil Engineers.—The highest marks in the October Associate Membership Examination have been obtained by Mr. C. Quartanos, of Newcastle-on-Tyne, and Mr. H. Knowler, of Sutton, Surrey. The Council have accordingly directed that Mr. Quartanos, who is ineligible for the Bayliss prize by reason of his not being a present or former student of the institution, receive honourable mention, and that the prize—of the value of £15—be awarded to Mr. H. Knowler, Stud.Inst.C.E., under the conditions of its foundation.

Steam Supply for Gas Producers.—The recovery of ammonia in producer gas plants necessitates the introduction of steam into the producer and it has been the practice to take this steam from the high-pressure boiler that supplies the engine, or to use a separate low-pressure boiler for generating the steam for the producer, or to take exhaust from the engine. Hitherto it has been the practice to use in such power installations steam engines or turbines either as condensing or non-condensing engines. In the latter case the quantity of exhaust steam available is far in excess of the requirements of the gas producer plant operating with the recovery of ammonia and supplying gas for raising the high-pressure steam. In the former case no steam is available for operating the producer plant. Mr. T. W. S. Hutchins, of Parkfield Works, Stockton-on-Tees, proposes in a recent patent to use condensing engines or turbines, the steam for the producer being obtained by tapping the steam in the engine or turbine at a point where the pressure is from 2lbs. to 3lbs. above that of the atmosphere. At this point, part of the steam is withdrawn through a suitable valve for use in the producer plant, the rest of the steam passing through the remainder of the turbine or through the low-pressure cylinders of the reciprocating engine to the condensers. By this procedure, it is claimed, there is produced an economy in constructional costs of machinery, and a considerable saving in operating costs, sufficient in some cases to render profitable the operation of steam power plants by means of boilers fired by gas made with the recovery of ammonia, where formerly such operation was unprofitable.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Process and apparatus for evaporating or concentrating fluids. Neuberger. 5872.
Apparatus for the transmission of heat from one fluid to another. Still, and British Still Tube Company. 10233.
Single and double-tube injectors for hot water. White. 23409.
Furnace grates. McLarty. 23417.
Railway and tramway vehicle brakes. Taylor. 23650.
Fly cutters and facing tools for use in milling machines and lathe turrets. Scott. 23709.
Flying-machine. Tuckfield & De Forges. 25399.
Production and employment of dry steam instead of saturated steam for driving, and generators therefor. Wallwork, Wallwork, & Williams. 25839.
Metallurgical treatment of pyrites or other iron sulphides. Wright. 26128.
Propulsion of vessels. Thornycroft, and John I. Thornycroft and Co. 26136.
Friction clutches. Electromotor Equipment Company, and Meacock. 26166.
Metallurgical furnaces. Stobie. 26184.
Power presses. Waller. 26274.
Manufacture of cold cut or pressed nuts. Stonehouse. 26294.
Internal-combustion engines. Redrup & Stanfield. 26322.
Combined internally-flued and water tube boilers. Haubentaller. 26362.
Apparatus for deep boring. Potter. 26451.
Variable-speed transmission mechanism. McBrair. 26538
Toothed wheels. Wallace & Stockley. 26574.
Pipe joint. Cloud. 26608.
Valve gear for internal combustion engines. Willans & Robinson, Ltd., and Willans. 26637.
Ball bearings for spindles. Guest. 26663.
Roller wheel bearings. Brewer. 26726.
Furnaces. Sackett. 26809.
Raising or forcing liquids and apparatus therefor. Humphrey and Rusdell. 26829.
Driving belts for grooved pulleys. Gray. 26837.
Driving belts. Gray. 26838.
Flying-machines. Voigt. 26855.
Moulding machine for foundry use. Neesham. 27200.
Process of rolling strips of steel or other metal to a thin gauge. Ainley, Willis, & McGregor. 27859.
Method of and machine for extruding metal tubes and rods. Lake. 27918.
Chain gearing for internal-combustion engines. Radford. 28062.
Internal-combustion engines of the two-cycle type. Garrard. 28741.
Gas meters. Gow, and Gas Meter Company. 28863.
Vertical multiflow surface condenser. Crighton. 28922.
Clutch mechanisms. Smith. 29204.

1912.

Centrifugal air compressors. British Thomson-Houston Company. 922
Pressure gauges. North. 1271.
Tinning of metal articles. Bullows. 1621.
Bushes or bearings for shafts. Hanna. 1698.
Hot rolling of round iron. Barge. 2122.
Clutching device for preventing a driven shaft rotating in excess of a predetermined speed. Peto & Radford, Ltd., and Genese. 2125.
Method of reducing the smoke from steel reheating furnaces. Stobie. 2597.
Variable-speed gear. Schweinfurter Pracisions-Kugel-Lager-Werke Fichtel, and Sachs. 2751.
Rotary motors. Leflman. 2772.
Steam hydraulic intensifiers. Davy Bros., Ltd., and Holmes. 2842.
Rotary gas engines. Augustine. 4297.
Multi-cylinder internal-combustion engines. Poppe. 4861.
Device for operating railway carriage couplings from the side of the carriage. Sandstrom. 4878.
Furnaces for melting, smelting, and refining. Price. 4989.
Railway rail joints. Foster & Foster. 7322.
Car couplers. Lake. 7779.
Steam superheaters for locomotive boilers. Robinson. 8141.
Valve mechanism for internal-combustion engines. Monohan. 9310.
Cutter discs of machines for use in mining coal. Mavor and Coulson, Ltd., and Mavor. 9346.
Lifting jacks. Templeton. 9607.
Rail-lubricating appliances. Warnecke. 9985.
Method of charging boilers with wood, straw, and similar material. Pokorny & Wittekind Maschinenbau Akt.-Ges. 10548.
Operation of casting pipes in rotating moulds and apparatus therefor. Orten Böving, and Molinder. 11340.
Change-speed gear. Janzon. 11919.
Linear dimension gauges. Hans. 11927.
Atomiser for the liquid fuel of explosion motors. Schneider. 12856.
Moulding plants for wrought-iron pulley bosses. Morris. 12924.
Rotary pumps. Slesazeck. 14836.
Gas producers. Dowson & Mason Gas Plant Company, and Stokes. 14893.
Couplings. Tilsch. 14966.
Cam-valve gear for engines. Lichtensteiner. 15157.
Steam traps. Marks. 15637.
Mechanical roasting furnaces. Hardingham. 16346.
Machines for casting metals. Dental Manufacturing Company, and Phillips. 16812.
Machine for measuring directly the hardness of metals. Guillery. 16879.
Safety arrangement for petrol tanks. Brionne. 17292.
Automatic stabilising apparatus for aeroplanes. Hayot. 18675.
Apparatus for melting, compressing, and forcing metal or alloys into moulds. Hanna. 19943.
Variable-gear. Foster. 20105.
Elastic-fluid turbines. Warwick Machinery Company (1908). 21763.
Milling machines. Trecker & Kearney. 24234.
Electric switches. British Thomson Houston Company, and Garton. 26119.

ELECTRICAL, 1911.

Switch apparatus for use with electric lighting of railway and other vehicles. Electric and Ordnance Accessories Company, and Etchells. 27010.
Electrical time switches. Hamilton, and Ferranti, Ltd. 28610.

1912.

Controlling continuous current reversible dynamos. Inrig and Inrig. 4119.
Electric heating devices. Cooper. 4399.
Bath for the electrolysis of iron. Tischenko. 5853.
Electric heating devices. Ferranti, Ltd., & Roothaan. 6182.
Telephone relays or repeaters. Stirrup. 8793.
Galvanometers. Hubert. 9410.
Means for indicating faults in the circuits of electrical transmission systems. Siemens Bros. & Co. 13854.
Electrical resistance devices. Ruhstrat. 15053.
Electric arc lights. General Composing Company, Ges. 15757.
Telephones. Sefton-Jones. 18129.
Electrical regulating apparatus. Lake. 18437.
Telephone systems. Western Electric Company. 20947.
Cooling of dynamos. Siemens Bros. Dynamo Works, Ltd., and Marden. 21472.

METAL QUOTATIONS.

TUESDAY, DECEMBER 17TH.

Aluminium ingot	90/- per cwt.
„ wire, according to sizes, &c. ......from	112/- „
„ sheets „ „ ...... „	120/- „
Antimony ......£39/-/- to	£40/-/- per ton.
Brass, rolled	9¼d. per lb.
„ tubes (brazed)	11½d.
„ „ (solid drawn)	9¾d.
„ „ wire	9⅛d.
Copper, Standard	£74/-/- per ton.
Iron, Cleveland	66/7½ „
„ Scotch	72/7½ „
Lead, English	£18/12/6 „
„ Foreign (soft)	£18/2/6 „
Mica (in original cases), small	6d. to 3/- per lb.
„ „ „ medium	3/6 to 6/- „
„ „ „ large	7/6 to 11/- „
Quicksilver	£7/8/6 per bottle
Silver	29⅜d. per oz.
Spelter	£26/10/- per ton.
Tin, block	£226/10/- „
Tin plates	15/3 „
Zinc sheets (Silesian)	£29/17/6 „
„ (Stettin; Vieille Montagne)	£30/5/- „



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Season Cracking in Brass.

THE troubles arising from what are known as season cracks in brass sometimes prove very serious, and until a few years ago the cause was involved in considerable obscurity, with the result that disputes often arose respecting responsibility when defects developed in articles under normal conditions of working and without apparent cause. These defects are entirely confined to articles that are drawn or rolled, such as tubes, wire, or sheet metal objects pressed in dies. Examination invariably revealed a crystalline structure at the crack and that the metal was more or less brittle around it. The extended use of drawn or rolled brass objects increased the necessity for probing the matter and led various investigators to try and arrive at some explanation. Some five years ago the matter was enquired into pretty fully by C. Diegel, in Germany, and he arrived at the conclusion that the trouble mainly arose in articles prepared from brass which were cold rolled or drawn, and further, that lead was an objectionable ingredient. Among other experiments made were some with hot and cold rolled 10 per cent. aluminium bronze. Hot rolled bars, it was found, did not suffer from season cracks, whereas cold drawn bars did, although the elastic limit of the material was higher. The reason put forward by him for this dissimilarity of behaviour was the lack of uniform density in the material, the difference of density being, roughly speaking, in the inverse proportion of the cross-section and obviously being greater with cold rolling than with hot, owing to the material yielding less when cold and consequently more work being put on the outside of the bar. Although these explanations may have accounted for the troubles then enquired into, they did not explain many others that were met with and in which it appeared clear from experience that external influences had a serious bearing on the defects observed. In particular it was found that ammonia compounds exercised a baneful effect, although it was scarcely discernible, while the metal beneath the surface, as far as could be ascertained,

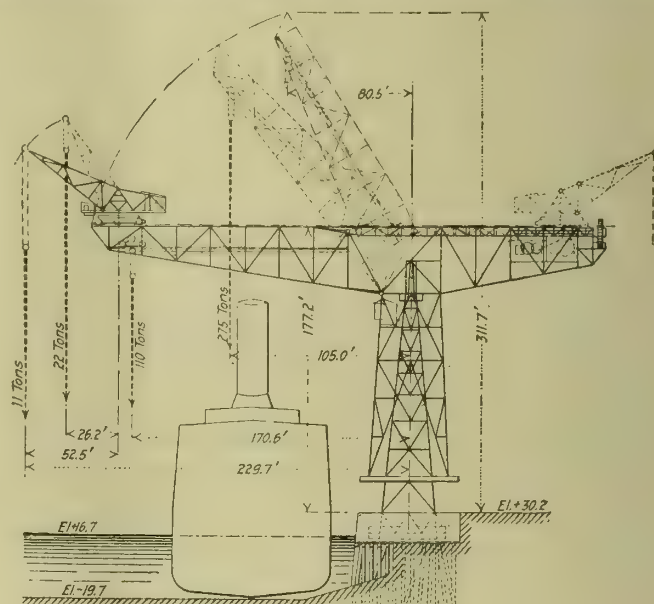
was sound. The action is obscure, and so far has not, we believe, been satisfactorily explained. It was suggested that it might be due to the dissolving out of the zinc, and some defects in condenser tubing containing this element appeared to confirm this view.

The extraordinary changes which may be effected in the physical properties of materials by chemical action, without any discernible alteration in appearance, is shown not merely in regard to brass, but also in regard to steel drawn tubes which when used in caustic liquor evaporators have frequently given trouble in an extraordinary way. In one instance we met not long ago the top and bottom ends of the evaporator tubes cracked and in some cases fractured, while a large number of the rivet heads of the steel plate shell also dropped off. Careful examination of the tubes showed that the cracks were confined to those parts of the ends which had been stretched by the expanders, but did not extend across that part of the tube which was compressed by the rollers against the tube plate, while the central portions of the tubes, between the tube plates not touched by the expanders, were not in the least affected. A cursory glance might have given the impression that the material and workmanship was bad, but this was not borne out by tests. The difference in the quality of the metal revealed by pieces cut from the ends and others cut out from the centre of the tube was remarkable. The end pieces, when cut into semi-circular pieces and flattened, split longitudinally, with very little distortion from the circular form, while the central specimens could be hammered without cracking. The behaviour of one set appeared to justify the conclusion that the material was bad, while the other equally demonstrated that it was of excellent character. So far we have seen no scientific explanation of this phenomena, though it has to be recognised in the design and working of caustic evaporators. Experience of these vessels shows that trouble of the kind alluded to becomes much more pronounced if the density of the caustic liquor is allowed to exceed 90° Tw., and further, that mild steel tubes are only attacked when the material is put in tension as they are by an expander. An interesting experiment bearing on this may be mentioned. Two pieces of mild steel tubing of excellent quality as determined by tests, but of different diameters, so that one could be driven tightly on the other, were prepared in this way, so that the outer one was in tension and the inner one was in compression. These were inserted for three months in a caustic liquor evaporator in which the density was not allowed to exceed 80° Tw. At the end of this period the rings were taken out and cut up. It was then found that the outer rings in tension were quite brittle, whereas the inner rings which had been in compression remained perfectly ductile.

Reverting to the question of the season cracking of brass, chemical action or density difference are not the only causes of trouble. The method of working when sheet is drawn into shapes seems undoubtedly capable of causing trouble, especially with hard brass. If the sheet is merely formed into shape and not stretched to any extent then there appears to be a greater liability for season cracks to develop subsequently than when the sheet is of thicker material, because the material is then stretched as it is forced through the die. It would seem as if in the former case the trouble arises because the stress is not uniformly distributed through the sheet, and obviously this lack of uniformity will be more pronounced in brass of more brittle composition. These various explanations do not, however, exhaust the subject. Attention has been drawn latterly to yet another cause of season cracking, especially where articles of brass, German-silver, or other alloys containing zinc -while even copper is not exempt are, after formation, electroplated. The trouble in these cases has been clearly traced to the action of mercury, which is brought into contact with them through the use of some mercury salt applied to the article to facilitate electroplating operations. Some interesting tests bearing on this are described in a recent issue of "The Brass World." Various pieces of hard and soft brass tubing, as well as some specimens of German-silver wire, were coated with a slight film of mercury and allowed to stand for several hours, after which, if slightly bent or flattened, surface cracking took place. This effect, it may be remarked further, was not confined to brass. Seamless phosphor-bronze tubing of nearly 98 copper and 2 tin, as well as soft copper sheet, behaved in a similar way. It is evident from the information and experience so far gleaned that season cracks in brass cannot be attributed wholly either to faults in the material, or to faults of treatment, and though particular effects observed may be somewhat obscure, present knowledge enables us to a large extent to differentiate the causes.

A LARGE CANTILEVER CRANE.

THERE has recently been completed at the works of Messrs. Blohm & Voss, shipbuilders, of Hamburg, for use in their own yard, a cantilever crane which is understood to be the largest ever constructed. According to particulars given in "Le Genie Civil," the crane is installed on the quay immediately alongside of the water-front. It comprises, as shown in the accompanying illustration, a central tower carrying a cantilever beam, the river end of which is pinned at the central pier so that it may be raised as shown by the dotted



250-TON CANTILEVER CRANE.

lines in the drawing. Additional movement is achieved by a smaller 10-ton crane which moves on the main bridge, by the small hoist which moves on the lower deck of the main bridge and by both longitudinal and rotary movements of the whole structure along the quay front. This crane can carry 11 tons hung from the smaller crane at a maximum distance of 229·7ft. from its centre, or a maximum of 275 tons from the end of the main bridge, a distance of 105ft. from the centre of the pier.

Zinc Water Pipes. — According to a German contemporary, zinc pipes are being used in that country for house water piping. The advantages claimed for them in comparison with lead and galvanised iron pipes are: they are less affected by water and its impurities than either of the latter; they do not give rise to local electric currents due to the contact of two different metals (in the case of galvanised iron pipes) and rapidly destroying the pipes; even if some zinc be dissolved by the water, it is harmless. Tests have shown that mechanically zinc pipe is much stronger than lead pipe. It also gives a very strong welded joint.

NEW DEVELOPMENTS IN CURTIS STEAM TURBINES.*

BY R. F. HALLIWELL.

(*Concluded from page 767*).

ALL turbines built by the British Thomson-Houston Company, except the smaller sizes for driving pumps, &c., are controlled by what is called nozzle governing, *i.e.*, the high-pressure steam is admitted to the turbine through separate groups of nozzles, the number of which is regulated in accordance with the load. The benefit derived from the avoidance of throttling losses is generally admitted, and practically all turbine builders attempt to avoid these losses by providing means whereby the area of open nozzles can be adjusted to suit the load. The construction of a satisfactory gear to do this automatically is not an easy matter, and it is not surprising that many makers prefer to simply fit hand operated valves instead of the complicated systems of levers, &c., which have been designed to accomplish the work. On the original vertical Curtis turbines, nozzle governing was managed by an ingenious and complex arrangement of steam operated valves, actuated by small pivot valves controlled by electric solenoids. The solenoids were in turn actuated by current distributed by a small controller worked by the governor. Although this gear worked very well when in good order, and in fact is still working well on many sets now running, and enabled very fine and close governing to be obtained, the possible sources of trouble are too many, and considerable experience of the gear is necessary to enable good results to be obtained.

On all modern turbines built by this firm nozzle governing is effected by a simple patent hydraulic gear, operated by oil under a pressure of from 40lbs. to 60lbs. per square inch from the lubricating system, which has been uniformly successful on the numerous turbines fitted with it. Steam is admitted to the first stage nozzles through several passages leading from the controlling valve chest, each passage receiving its separate supply of steam through its own controlling valve. The controlling valves are of ordinary mushroom type, with steam on top tending to keep them shut, the steam pressure being assisted by springs. The valves are opened by means of tappets, actuated by cams in a manner similar to that found on motor car engines. The cams are mounted on a cam shaft capable of being turned through nearly a complete circle, and are so disposed that when the cam shaft is rotated the valves are opened in succession. The movement of the cam shaft is effected by a rotary servo-motor, consisting of a radial wing secured to a prolongation of the cam shaft, and fitting in a cylinder concentric with the cam shaft, and having a radial fixed partition, on either side of which oil is admitted or released as required. The flow of oil is regulated by a pilot valve controlled by the governor through a floating lever, one end of which is connected to the governor, the other end being moved by the cam shaft by means of a rack and pinion, the pilot valve being connected to the centre of the lever. The effect of this "follow-up" arrangement is that any movement of the cam shaft in response to the governor returns the pilot valve to its central position, and cuts off both ingress and egress of oil, with the consequence that the rotation of the cam shaft and the number of valves admitting steam bears a definite relation to the movement of the governor.

The action is extremely sensitive, and though taking long to describe in words, actually no lag is apparent, the movements of governor and cam shaft taking place practically simultaneously. Owing to the governor having to only move a small pilot valve,

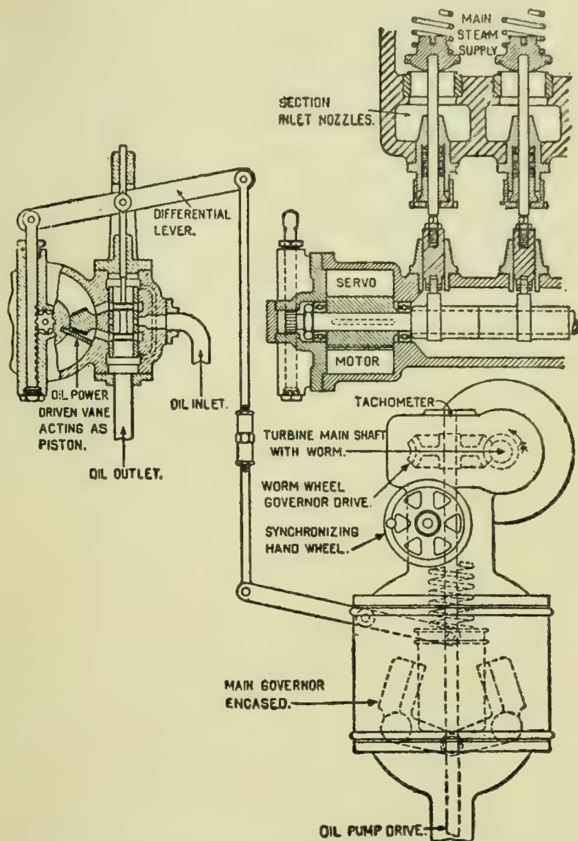


FIG. 16.—GOVERNOR GEAR. CURTIS TURBINES.

a very sensitive governor can be used giving very fine speed regulation. Since the force required to open the valves is transmitted directly through tappets, and the pressure is always in the same direction, there is no lost motion to be taken up, and liability to hunt is avoided. The governor is driven by worm gearing at the end of the turbine shaft, and an extension of the governor shaft drives the oil pump. A diagram of this governor gear is shown in Fig. 16, and an illustration of a

* Paper read before the Manchester Association of Engineers, December 14th, 1912.

Steam Consumption of Horizontal Curtis Turbo-Alternators.

Manufactured by the British Thomson-Houston Company, Ltd., Rugby.

Size of Turbine.	Type.	Customer.	Date.	Load. Kw.	Press. Lbs. sq. in. Gauge.	Super-heat °Fah.	Vacuum Ins. Hg. 30in. Bar.	Water Rate. Lbs. Kw. Hour.	Overall Thermal Eff. %
5,000 Kw.	High	County of London,	May,	4,450	149	140	27·95	14·44	67·3
1,500 R.P.M.	Pressure	E. S. Co., Ltd.	1912	5,626	147	163	27·6	14·36	68·5
3,000 Kw.	High	Olympia Oil and Cake	April,	2,987	140	144	26·83	15·96	65·8
1,500 R.P.M.	Pressure	Co., Ltd.	1911						
2,000 Kw.	High	Yorkshire Waste	May,	1,995	142	153	27·23	15·30	66·5
3,000 R.P.M.	Pressure	Heat Co.	1912						
1,500 Kw.	High	Borough of	Nov.,	1,476	139·4	103	28·36	14·93	65·3
3,000 R.P.M.	Pressure	Fulham.	1911	2,238	136·6	97	27·96	14·62	69·2
1,500 Kw.	High	Humber Comm. Railway	Feb.,	1,488	148	210	27·83	14·30	65·8
3,000 R.P.M.	Pressure	and Dock Co.	1912						
1,000 Kw.	Mixed	Broken Hill Mines,	May,	985	0·97	34	26·46	34·90	67·5
3,000 R.P.M.	Pressure	Australia.	1911						
500 Kw.	Mixed	Rufford	May,	520	0·76	34	27·68	30·00	67·8
3,000 R.P.M.	Pressure	Colliery.	1912						
350 Kw.	Mixed	English Sewing Cotton	July,	361	1·00	25½	27·70	34·50	58·7
3,000 R.P.M.	Pressure	Co., Matlock Bath.	1911						

NOTE.—The above efficiencies are calculated by means of Peabody's Steam and Entropy Tables.

1,500 kw. 3,000 r.p.m. turbine, in Fig. 17, shows the gear on the end of the turbine.

Mention has not yet been made of mixed-pressure turbines, which at the present time take such a prominent place in the production of cheap power in places where reciprocating engines already exist or have to be employed. The economic reasons which render the mixed-pressure turbine so advantageous have been dealt with so fully in the past that it will be unnecessary to touch on them here. It is sufficient to say that in the British Thomson-Houston mixed-pressure turbine the same general principles of construction are employed as in the high-pressure machine, and the simple and robust construction which is peculiarly possible with turbines built on the Curtis system renders them particularly suitable for situations in which mixed-pressure turbines are most often found.

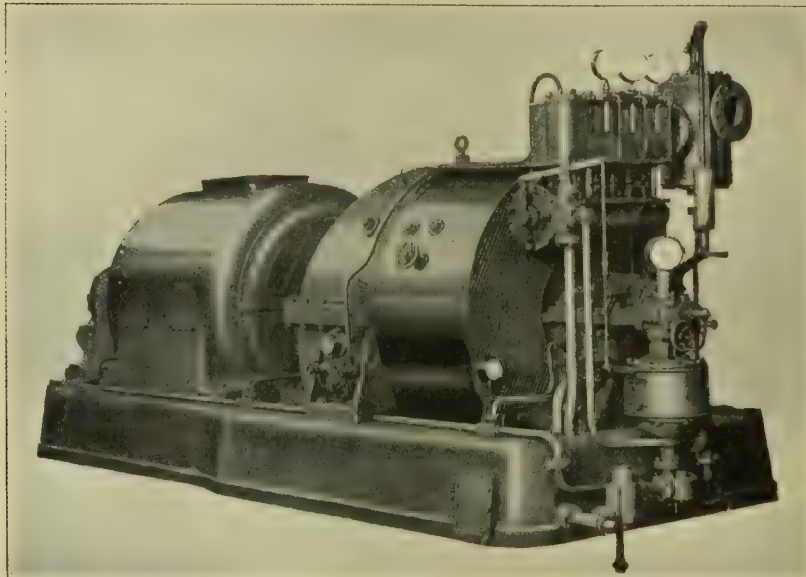


FIG. 17.—1,500 KW. CURTIS TURBINE FITTED WITH GOVERNOR GEAR.

In mixed-pressure turbines the low-pressure steam is generally admitted to an intermediate stage where it mixes with steam which has already done work in the high-pressure stage. In many cases, however, where the utmost economy under high-pressure conditions is not essential, a special high-pressure stage is not employed, the high-pressure steam and low-pressure steam both being admitted to the same first stage wheel, of course through separate nozzles, the two supplies of steam not mixing until both have done work in the first stage. This arrangement presents many advantages, inasmuch as the utilisation of the low-pressure steam available is not affected by the quantity of high-pressure steam which is being admitted to the turbine. The same cannot be said of the ordinary mixed-pressure turbine, with a separate high-pressure stage, in which the low-pressure steam mixes with the already partially utilised high-pressure supply, the two together passing through common nozzles to the second stage. In this case, since the second stage nozzles have to be designed to pass a certain maximum quantity of steam at the low-pressure inlet pressure, if from any cause the amount of high-pressure steam being used is larger than that allowed for, the quantity of low-pressure steam which can pass through the nozzles will be correspondingly reduced, with the effect that the turbine is incapable of utilising its full quantity of low-pressure steam, although there may be an ample supply available.

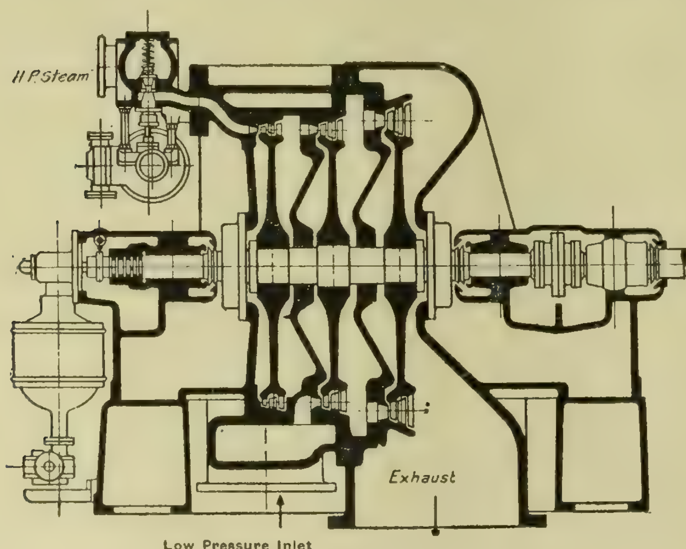


FIG. 18.—MIXED-PRESSURE TURBINE.

The great advantage of having separate low-pressure inlet nozzles will therefore be apparent, but it must be remembered that in order that the pressure in the second stage may not affect the flow of steam through the first stage nozzles, it is necessary that the second stage pressure be not greater than about 58 per cent. of the first stage pressure, that is, the critical point below which the weight of discharge through a nozzle is independent of the discharge pressure and depends solely on the initial pressure. To be well on the safe side of this critical point it is necessary that a considerable proportion of the energy be utilised in the first low-pressure stage, and as will be realised from the study of the types of impulse turbines, the Curtis turbine is practically the only one which enables this to be done without loss of efficiency. With the reaction type of turbine in which steam is admitted around the whole circumference, this description of mixed-pressure turbine is impossible.

The British Thomson-Houston Company have recently patented, and are now building a new type of mixed-pressure turbine, shown in Fig. 18, in which the advantages mentioned above in respect to low-pressure steam utilisation are combined with excellent economy on high-pressure steam. This turbine has a separate high-pressure stage, the steam from which, instead of mixing with the low-pressure steam and then passing to the second stage, as in ordinary mixed-pressure turbines, goes into separate nozzles in the second stage, quite distinct from the nozzles provided for the low-pressure steam, the two supplies not mixing until they have passed through the second stage in the same manner as previously described. Owing to the provision of special nozzles in the second stage to receive the partially utilised high-pressure steam, these nozzles can be designed to suit high-pressure conditions, with the consequence that with this type of turbine it is possible not only to obtain the advantages mentioned previously, due to the separate low-pressure inlet nozzles, but also an efficiency with high-pressure steam very little worse than that obtainable with a pure high-pressure turbine.

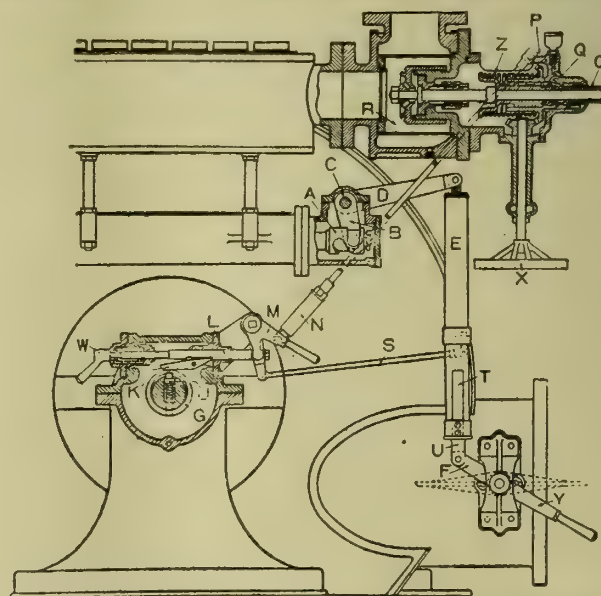


FIG. 19.—MIXED-PRESSURE TURBINE. SHOWING METHOD OF OPERATING LOW-PRESSURE CONTROLLING VALVE.

It should be noted that when this turbine is operating with low-pressure steam alone, the pressure in the space surrounding the high-pressure wheel is only that found at the entrance to the third stage, which being quite low produces small rotation losses, so that the loss in efficiency as a low-pressure turbine is almost negligible.

This design of turbine has been criticised for the fact that, when operating under mixed-pressure conditions with a quantity of low-pressure steam below the normal, the inlet pressure of the low-pressure steam is lower than it would be if the pressure were kept up by the admixture of the high-pressure steam which is being used, and that therefore the low-pressure steam consumptions suffer. It would certainly seem that to claim an advantage for the maintenance of pressure in an ordinary mixed pressure turbine, due to the admission of high-pressure steam, is in the nature of making a virtue of a necessity, and that any slight theoretical gain in economy under certain abnormal conditions is more than counterbalanced by the ability to utilise at all times the full quantity of exhaust steam. This is especially so if due to reduced vacuum or steam pressure, conditions which in many places are the rule rather than the exception, the quantity of high-pressure steam to be dealt with is considerably larger than

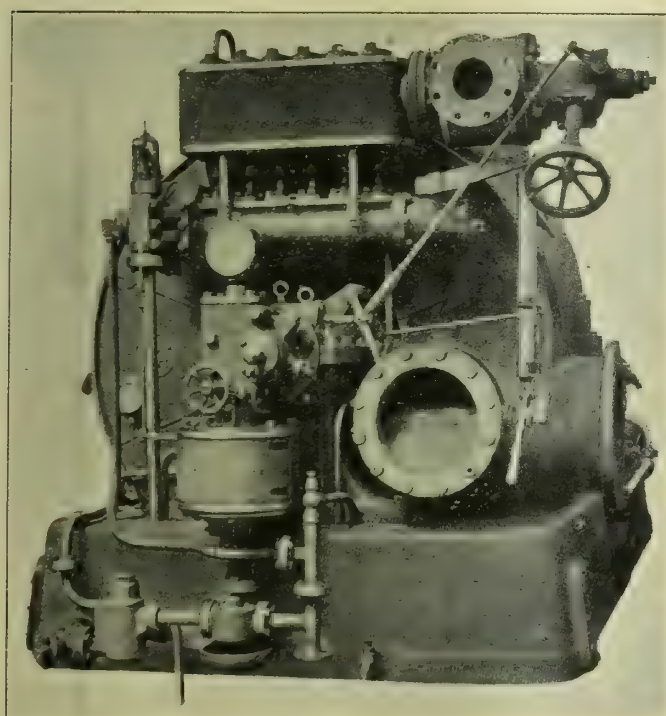


FIG. 20.—MIXED-PRESSURE TURBINE FITTED WITH LOW-PRESSURE CONTROLLING GEAR.

was originally expected. Also in the case of turbines working with regenerative accumulators, the reduction in pressure as the quantity of low-pressure steam decreases enables full advantage to be taken of the regenerative capacity by using the British Thomson-Houston patented system of installing an automatic shut-off valve on the far side of the accumulator.

In the British Thomson-Houston mixed-pressure turbines the low-pressure controlling valve, which is usually of the butterfly type, is operated by a bell crank actuated by a spiral cam at the end of the cam shaft, as shown in Fig. 19. The cams are arranged so that the first high-pressure valve is not opened until the low-pressure valve is wide open, so that so long as there is sufficient low-pressure steam to deal with the load no high-pressure steam is used.

In many cases where mixed-pressure turbines are operated in electrical connection with reciprocating engines, from which the low-pressure steam is obtained, no controlling valve for the low-pressure steam is fitted, or if fitted is rendered inoperative, the turbine being kept to speed by the interlocking of the engine and turbine generators, and utilising all the exhaust steam available. High-pressure steam can be admitted when dealing with heavy loads by adjusting the synchronising gear, so that if left to itself the turbine would run a little slower than the normal speed of the station. In this way the turbine governor will only come into operation when the total load is such as to cause the station speed to drop a certain amount below the normal. A set of 3,000 kw. capacity has been recently supplied to the Lancashire, and Yorkshire Railway for their Formby station, which will work in this way.

Another method of governing mixed-pressure turbines adopted when the turbine receives the exhaust from an engine or engines

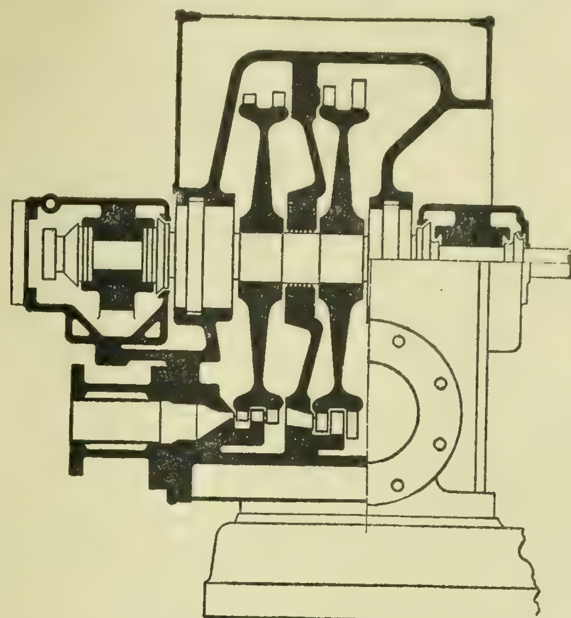


FIG. 21.—TWO-STAGE TURBINE FOR DRIVING PUMPS AND COMPRESSORS.

not electrically connected with the turbine, is to arrange the low-pressure controlling gear to operate a by-pass either to a lower stage or to the condenser. By this means should the quantity of exhaust steam be more than sufficient for the load on the turbine the by-pass opens, and reducing the back pressure on the engine enables it to do its work with less steam, the quantity of which is re-adjusted by the engine governor. With this arrangement the back pressure on the engine, and consequently the quantity of steam used by the engine, is kept down to the minimum required for the load on the turbine, and maximum

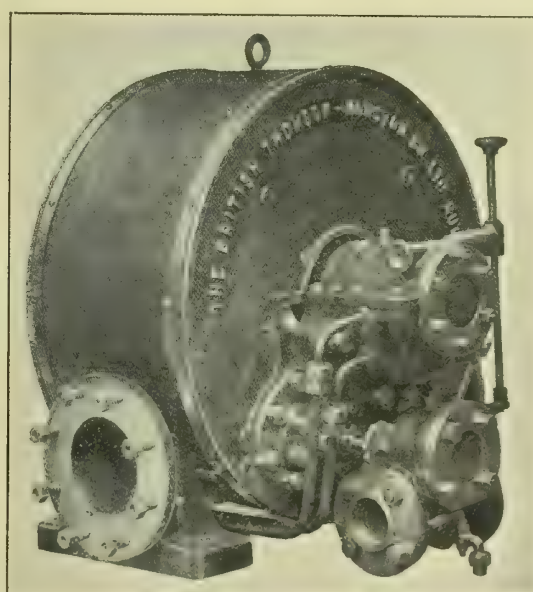


FIG. 22.—TWO-STAGE TURBINE FOR DRIVING PUMPS AND COMPRESSORS.

combined efficiency is thereby obtained. A turbine fitted with this form of gear is shown in Fig. 20, the flange on the extreme right being the low-pressure inlet, with a free passage to the turbine, and the flange in front being the by-pass to the condenser.

Where mixed-pressure turbo-alternators run in parallel with high-pressure sets of similar or larger size, it becomes necessary to slightly modify the governor gear to enable a proper distribution of load to be secured in the event of a partial or complete cessation

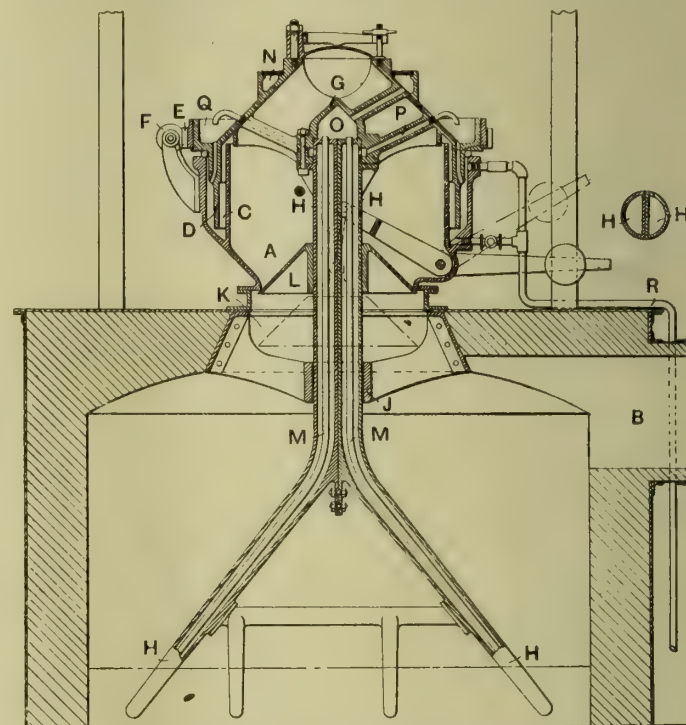
of the low-pressure supply. This is easily and simply provided for by a duplex arrangement of the pilot valve regulating the oil supply to the servo motor previously described. The valve itself, which remains as before, is surrounded by a sleeve or hollow outer valve, actuated by a piston exposed to the low-pressure inlet pressure in such a way that if this inlet pressure falls the position of the ports admitting oil to the servo motor is altered, and the cam shaft is rotated sufficiently to admit enough high-pressure steam to deal with the load without the governor being affected, and therefore without any change in speed. Restoration of the low-pressure inlet pressure results in the replacing of the parts in their original positions.

The recent introduction of rotary air pumps and high-speed centrifugal pumps has led to the use of small steam turbines for driving these pumps. This presents many advantages in ease of starting up and the removal of electrical gear from undesirable situations, and also permits of considerable gain in heat efficiency if the small turbine can exhaust into a feed-water heater, owing to the utilisation of the latent heat in the steam. Even if it is not possible to exhaust into a heater, fair economy can be obtained by exhausting into an intermediate stage of the main turbine at a pressure of 5lbs. to 10lbs. above the atmosphere. Although there is of course no difficulty in making these turbines suitable for exhausting into a vacuum, it is not as a rule worth the additional expense for the slight gain that is possible. These small turbines are also suitable for driving air compressors, blowers, gas exhausters, and for other purposes where a high speed of rotation is possible. The sizes developed by the British Thomson-Houston Company range from 15 h.p. to 250 h.p. for speeds of from 7,000 to 1,500 revs. per minute. The general design follows that of the larger turbines, but governing, when used, is effected directly by the governor by throttling the whole steam supply. Ring lubrication is used, with water jackets to prevent the heat of the casing being transmitted to the oil. A diagrammatic section through a two-stage turbine is given in Fig. 21, and the outside appearance is shown in Fig. 22, which is a photograph of a 55 h.p. 3,600 revs. per minute 18½in. diameter turbine.

The table on page 795 contains some recent steam consumption figures obtained on official tests with Curtis turbines built by the British Thomson-Houston Company, Rugby, to whom the author wishes to express his thanks for permission to publish these and other particulars.

CHARGING HOPPERS AND REVOLVING POKERS FOR GAS PRODUCERS.

We illustrate herewith a design of gas producer of the type having rotatable water-cooled pokers for agitating the fuel to prevent the possibility of its caking or clinkering. The producer, which is the invention of The Dowson and Mason Gas Plant Company, Ltd., of Alma Works, Levenshulme, Manchester, and Mr. Jas. W. B. Stokes, consists of the usual firebrick-lined metal casing, and has a central charging hopper A and an outlet B for the gas produced. An annular channel C is formed around the upper end of the lower part of the charging hopper. The upper part of the hopper is separate from the lower part, being carried on a ball bearing and having a cylindrical web D extending within the annular channel C. A wormwheel E is formed on the outer surface of the upper part of the hopper. This wormwheel gears with a worm F on a shaft driven through gearing from any suitable source of power, so that on rotation of the shaft the upper part of the hopper is made to revolve. Webs within the rotatable part of the hopper carry a central conical cap G within which the upper end of a central member projects. This member consists of two D-shaped tubes H with their flat sides adjacent and secured| together by bolts passing through extensions of the lower ends of the flat sides. The central member H is secured to and suspended from the conical cap G by flanges on the cap and on the tubes bolted together, so that the central member rotates with the upper rotating part of the hopper. The central member H also passes through a guide J within the producer, this guide being made in halves each carried by a web bolted to the lining forming the circumference of the charging aperture K in the top of the producer, which aperture is controlled by the usual charging bell L of the hopper. The lower portions of the tubes H, beyond where they are joined together, extend out at an angle towards the sides of the producer and form pokers which agitate the fuel as they revolve. A distance piece extends between the two angled pokers and carries auxiliary pokers depending into the fuel in the central zone of the producer. The arrangement of pokers thus provided ensures thorough agitation of the fuel over practically the whole area of the producer. Central tubes M extend within the tubes H so that the main pokers formed by these latter tubes may be water-cooled, the water passing as usual down through the central tubes and up again through the tubes H. The cooling water is supplied first to an annular trough N on the exterior of the rotating part of the hopper from whence it flows to a collecting chamber O in the interior of the conical cap G, into which chamber the upper ends of the central tubes M project, then after the water passes through the pokers it leaves the



CHARGING HOPPERS AND REVOLVING POKERS FOR GAS PRODUCERS.

upper ends of the tubes H, through passages P, opening into a second trough Q on the rotating part of the hopper. From this second trough the water passes through openings formed through the bottom of the trough into the annular channel C, extending around the lower stationary part of the hopper. The cylindrical web D on the upper rotating part of the hopper depends within the channel C, so that when the channel is filled with water the upper part of the hopper is luted, making an effectual gas-tight joint between the two parts of the hopper. The overflow from the lute C is led by a pipe R to the usual water lute at the bottom of the producer. A pipe, fitted with a stopcock, extends between the bottom of the lute C and the pipe R, so that the lute may be drained when desired. The hopper is charged as usual through an opening in its uper part controlled by a hinged door. When charged and the door closed the charging bell is lowered by means of the usual counterweighted lever arrangement to allow the charge to fall from the hopper into the producer.

Electricity in Mines. — According to the report on mines and quarries recently issued, electricity was newly introduced into 46 mines in 1911, as against 40 in the previous year. It is mentioned that the electricity special rules in force during 1911 merely required that the introduction of electricity should be notified. No particulars were asked for, and none as a rule were given. The matter has, however, been remedied by the Coal Mines Act, 1911, and a complete classification of the different systems of distribution, together with a measure of the growth of the use of electricity in mines, would be possible for the future.

SUGDEN'S SUPERHEATERS.

SINCE the modern introduction of superheating much greater attention has been paid to the design of these adjuncts to steam generation, and it is to this to a large extent that their success and general recognition as aids to fuel economy is due. Amongst the firms who have given prominent attention

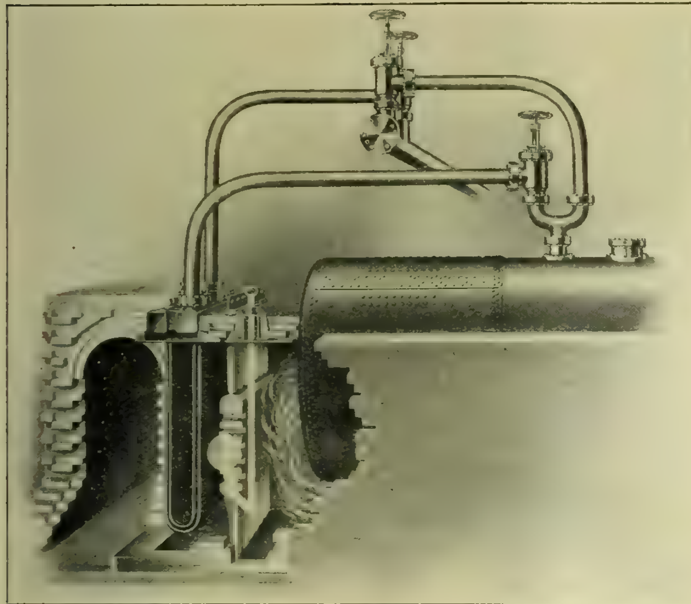


FIG. 1.—SUGDEN'S STANDARD TYPE OF SUPERHEATER (DAMPERS CLOSED AND SUPERHEATER ISOLATED).

to, and been most successful in introducing, this kind of apparatus is Messrs. T. Sugden, Ltd., of Fleet Street, London, E.C., and we illustrate on this and the following page an improved sectional design introduced by them. The principal feature of the superheater relates to the better provision for securing the several sections to the headers by a large central bolt, thus dispensing with the set screws and studs previously used for this purpose, and which are liable to

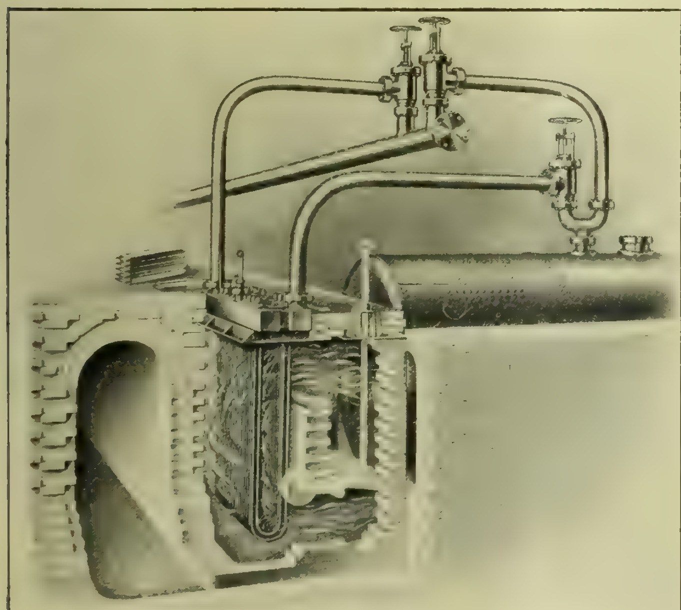


FIG. 2.—SUGDEN'S STANDARD TYPE OF SUPERHEATER (DAMPERS OPEN AND SUPERHEATER IN OPERATION).

deteriorate under the oxidising action of the flue gases, and break off if the sections have to be removed.

In the standard type of superheater made by this firm, which we described on a previous occasion, and which is shown in Figs. 1 to 4, the whole of the tubes are expanded into the headers. Its general simplicity and convenience are obvious, since it permits of any tube being taken out separately through the openings between the headers in case of renewals being required.

Figs. 5, 6, and 7 show the new sectional form of superheater, designed to meet cases where this type is more suitable or preferred. The advantage of this arrangement is that any of the tubes can be disconnected from the header and withdrawn without disturbing the header itself. Each group of four tubes is complete in itself, the ends of the tubes being expanded into the flange, which is united to its respective header by means of a large central bolt in the manner shown in Figs. 8 and 9, and for which purpose convenient hand holes are cut in the opposite side of the header, and for tightening purposes an extended nut with a recess for a box key is conveniently arranged between the tubes. Fig. 5 illustrates the operation of removing a set of tubes from a superheater of this type.

Attention may also be drawn to a new design of central damper for permitting the boiler to be worked with or without the superheater. The general arrangement will be readily apprehended from the photo views, Figs. 1 to 4, showing its application to an ordinary Lancashire boiler. The swivel damper A is fixed in an opening in the lower part of the

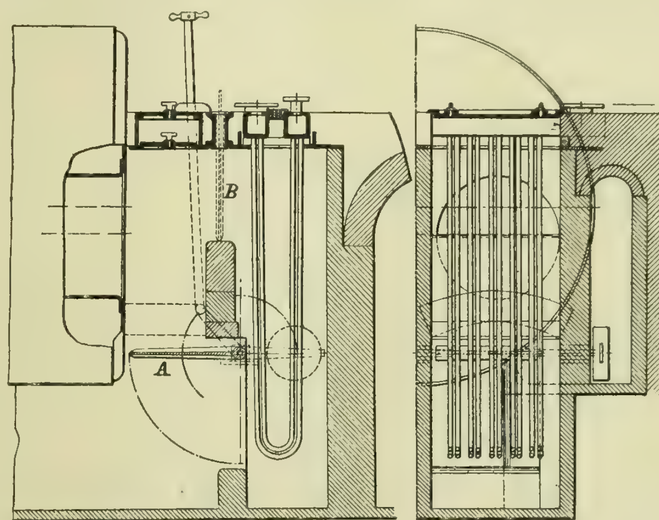


FIG. 3. FIG. 4.
SECTIONAL VIEWS OF SUGDEN'S STANDARD SUPERHEATER.

wall at the back of the down-take. This wall, it will be further noticed, is not carried right to the top, but is provided with an opening which can be closed if desired with baffle plates or slab dampers operated from the top. When the superheater is in use, these slab dampers are withdrawn, while the lower swivel damper is swung into a horizontal position, thus leaving a free passage for the gases through the superheater tubes, as shown in Figs. 2 and 3. When it is desired to isolate the superheater the swivel damper at the bottom is swung into a vertical position, and the slab dampers inserted from the top, so closing the superheater chamber, and leaving the gases to pass directly from the side flues to main flue.

The steam connections to the superheater are controlled in an equally convenient way by the valves shown in Figs. 1 and 2. When not in use the valve connecting the boiler to the steam main is opened, and the other two valves closed. This change can be made at any time without interfering with the working of the boiler or incurring risk of overheating the tubes, which, without the isolating damper arrangement,would be liable to burn away, while removals or repairs to tubes can be effected during the ordinary course of working. This is an advantage which will be apparent to all who have to do with the working of such apparatus, and who will be aware that, as commonly arranged, such repairs or renewals cannot be effected without disconnecting the superheater from the boiler.

Personal. — The Council of the University of Sheffield at a recent meeting decided to appoint Prof. Hardwick Emeritus Professor of Mining, to mark its recognition of his long and valued service. The Council also appointed Mr. G. B. Brook to the post of Lecturer in Non-ferrous Metallurgy, and Mr. E. C. Glauert to the post of Demonstrator in Non-ferrous Metallurgy.

INVESTIGATION OF THE IRON MELTING PROBLEM.*

BY A. W. BELDEN.

In order to investigate iron-melting problems, a 36in. Whiting cupola was installed in the research laboratory of the United States Bureau of Mines, at Pittsburg. Samples of the gases during their travel from the tuyeres upward were taken and analysed and the temperatures of the fuel bed were measured. Upper and lower tuyeres were provided, but the upper set was not used in any of the tests. The four horizontal tuyeres measured 4in. by 6in. on the outside and 3in. by 13in. on the inside. The tuyere area was 96in. and the area of the cupola, lined to 27in., 573 sq. in., a ratio of 1 to 5·96. The cupola was connected by a 10in. pipe, 15ft. long, with a No. 2 10in. by 35in. horizontal Roots blower, belt-driven by a 10 h.p. motor. This blower delivers a definite volume of air per revolution when running free and the loss due to slippage is a definite and uniform quantity under any definite pressure.

A reciprocating counter attached to the main shaft of the blower gave accurate determinations of the revolutions, and a Pitot tube connected to a recording pressure gauge gave pressure at any time or an average over any period of time. The blower

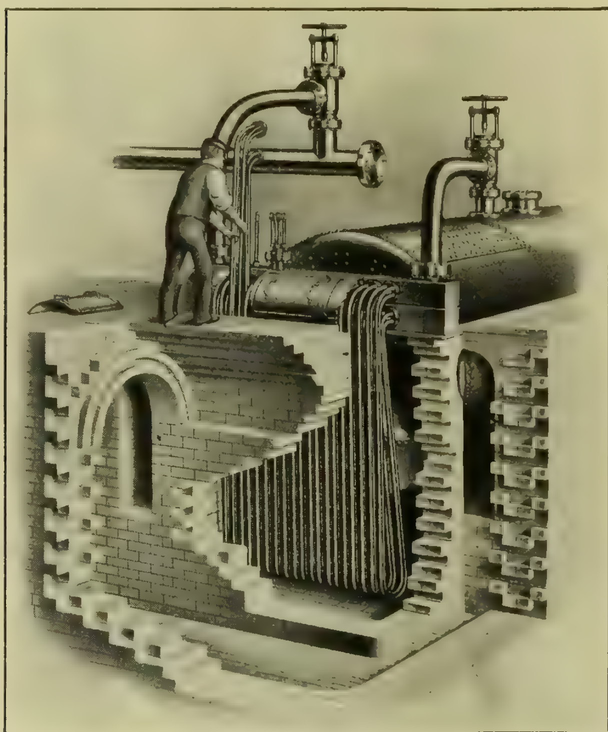


FIG. 5.—SHOWING SUGDEN'S SECTIONAL SUPERHEATER AND OPERATION OF REMOVING OR REPLACING A SECTION. (See page 799.)

was calibrated at 2, 4, 6, 7, 8, and 16 ounces, and a curve was constructed showing the slippage revolutions per minute at various pressures, ranging from 0ozs. to 16ozs. Knowing the amount of air delivered per revolution, in these tests 4·8 cubic feet, the revolutions, the average pressure and the slippage at this pressure, the total amount of air delivered was easily calculated.

Preliminary tests were made with varying volumes of air per minute, and the results suggested the use of 1,000 cu. ft. per minute as a normal condition. The varying pressures due to size of coke, the position of pieces of coke with reference to other pieces and the side walls, the effect of slagging and hanging, and other conditions, made it impossible to regulate the air supply, but the average of all tests approximated this figure of 1,000 cu. ft. per minute. The cupola was divided into four sections, designated *A*, *B*, *C*, and *D*, and 2in. holes were cut through the wind box and inner shell. Through each of these a 1½in. pipe, 10in. long, was passed. The inner end extended 1in. past the inner shell and into the brick lining, while the outer end extended 1in. outside the wind box and was threaded to take a cap adapted

* Paper presented at the Buffalo meeting of the American Foundrymen's Association.

to fit tightly the gas sample tubes when inserted. On the opposite side of the cupola holes were cut at corresponding levels and were fitted with 3in. pipe in a similar manner. Through these the temperature measurements were taken. Later developments made a fifth section necessary. Coke alone was used without iron or flux.

The tubes for collecting gas or measuring temperature were then placed in position. About 24in. of coke were placed upon sufficient wood to ensure proper kindling. The fire was lighted, and the coke was allowed to ignite and burn until the top showed bright. Coke in small amounts was added from time to time, well above the top tube, each succeeding charge being held until the preceding charge burned through. After the last small

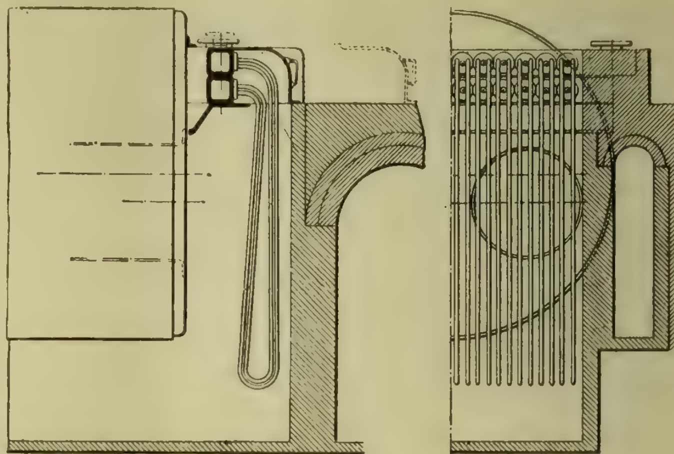


FIG. 6. FIG. 7.
SECTIONAL VIEWS OF SUGDEN'S SECTIONAL TYPE OF SUPERHEATER. (See page 799.)

charge was added, sufficient time was given to ensure its burning evenly over the whole surface. This was an indication that the burning was over and through the whole bed of coke and not localised as sometimes happens when proper precautions are not taken. The kindling wood was always completely burned out before adding the last coke. This last amount of coke brought the total charge up to within 6in. of the charging floor. The total charge was approximately 750lbs. for each test. Ten minutes after the total charge was added, the blast was turned on and continued for 15 minutes before the test began. The reason for allowing this length of time was to ensure uniform conditions over the whole fuel bed, and was decided upon as being more than necessary under regular commercial practice for the appearance of iron at the cupola spout, an indication that melting

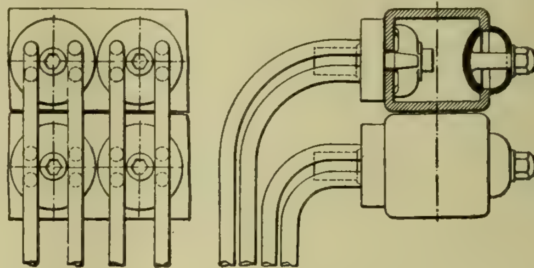


FIG. 8. FIG. 9.
DETAIL VIEWS SHOWING CONNECTIONS TO HEADERS IN SUGDEN'S SECTIONAL SUPERHEATER. (See page 799.)

had begun. The gas collecting tubes were kept cool by cold water introduced into the farther end through a ½in. copper tube and passing out through a ¼in. iron pipe.

As was to be expected, the samples taken at different times showed many variations. The flow of the blast after entering the tuyeres was probably changing during the whole period, seeking the easiest means of escape inwardly as well as upwardly along the lines of least resistance. The largest volume undoubtedly flowed up the side walls, and this as well as the part penetrating toward the centre was more or less deflected, depending on the obstructions met with. These effects were especially noticeable during preliminary work when coke was charged in varying sizes as received.

A study of the conditions at the centre line of the cupola showed the practical absence of oxygen at all sections, the small

amount recorded being within the range of the probable error of the method of analysis or the chance happening of the penetration of some small amount of the blast.

One inch above the tuyeres the oxygen of the blast was reduced by an amount necessary to form 4·5 per cent. CO_2, and this formation of CO_2 was rapidly increased in the first 6in. with a corresponding decrease in O_2 and with little CO formation. This would indicate a fierce burning and a great rise in temperature.

The tests indicated that actual combustion of the fuel takes place around an inverted cone of the fuel bed, the apex of this cone being at the centre in line with the bottom of the tuyeres and flaring out to the lining at a point 20in. above. The height of the melting zone above this section is determined by the physical condition of the coke and the rate of heat absorption of the iron. If the coke is porous the charges of iron should be small to prevent the coke burning out and letting the iron down into the oxidising zone before melting is accomplished. If the coke is heavy and dense, or if anthracite coal is used, the charges may be made large as the fuel burns more slowly and gives time for increased melting. At some point above this zone the temperature, while still high enough to melt iron, is not high enough to impart its heat quickly and give hot iron. The passage of this melted iron through the lower zones, although the temperature in these zones be exceedingly high, is too rapid for the absorption of enough heat to materially raise its temperature and cold iron is the result. These experiments confirm the general opinion that the hottest part of the cupola is where the lining is most burned out. An examination of the curves which were plotted showed that the highest temperature corresponds with that section where oxygen is entirely absent across the whole cross-section. This section is about 20in. above the tuyeres.

The ideal melting zone is probably inside the lines drawn through the points of highest carbon dioxide and absence of oxygen, as determined from analyses of the gases. It is manifestly impossible to confine melting to such a zone, and results of these experiments warrant the conclusion that the best results are obtained if the iron is melted at that point in the cupola where the highest temperature and absence of oxygen obtain across the whole cross-section of the fuel bed. This zone on the cupola tested was 20in. above the tuyeres when 1,000 cu. ft. of air per minute are blown. Under other conditions of air this zone will be raised or lowered, higher up if the blast is increased and lower down if the blast is reduced. Experimental determination of this point is not necessary. The bellying out of the lining of the cupola is a perfect index of this practical melting zone, and is at the point of highest temperature and absence of oxygen. Care must be taken not to melt below this zone as the oxygen of the blast is not entirely removed and the iron will be oxidised or burned. The extent of this burning is dependent upon the distance below the proper melting zone and the lateral position in the fuel bed. Just below this melting zone oxygen is still found at the lining, and the area of this oxidising section increases as the distance down increases until the whole cross-section at the tuyeres shows the presence of this damaging element.

The whole problem of hot iron free from effects due to oxygen is solved by using small charges evenly distributed on the fuel bed, and confining the melting to a few inches above the point shown by the burning out of the lining to be the hottest cross-section of the fuel bed. If the first charge of iron is so placed that melting begins, for example, 6in. or 8in. above this cross-section and is completed before any of the iron gets below this point, and the following coke and iron charges are so regulated as to maintain this melting zone, the best possible results will be obtained.

It is further pointed out by these experiments that the use of upper tuyeres is not necessary, but a positive detriment to the production of the best iron. The introduction of air into the fuel bed above the tuyeres, even though in small amount, increases the liability of injurious effect from oxygen and serves no useful purpose. The increased tonnage supposed to be due to the use of upper tuyeres can be just as easily accomplished by blowing in through the bottom tuyeres the proper volume of air.

The Size of Steamships.— An indication of the increase in size and cost of steamships is afforded in the case of the P. & O. Australian line. Nine steamships which cost £1,805,000 have been replaced by nine others valued at £2,958,000.

THE LESSONS OF COLLISIONS AT SEA AND SOME SUGGESTIONS.

At the Institute of Marine Engineers, Stratford, London, E., on Monday, December 16th, a paper on "The Lessons of Collisions at Sea, and Some Suggestions" was read by Mr. G. W. Newall. Mr. John McLaren (Member of Council) presided.

In the course of his paper, Mr. Newall said the scheme he wished to put forward with regard to collisions at sea entailed no costs such as the addition of any special plant or apparatus would demand, but simply set forth a few rules and requirements that should be observed and carried out by the officers in charge. The recent loss of the "Titanic" had stirred up much thought and mechanical invention throughout the maritime world to meet or avoid such disasters in the future. Drastic changes would no doubt be made in the direction of new rules and regulations for dealing with passenger ships, such as routes altered to suit seasons, increased facilities for sending and receiving "wireless" messages and danger signals, head search lights experimented with, &c. At the same time, it should be borne in mind by those who had to deal with this class of vessel that the tendency to hinder the steady progress of ocean transportation by unnecessary precautions for safety had an element of danger. He suggested that the Board of Trade should be approached with the view of promoting a maritime recommendation that in all cases of collisions of ships —where possible—the colliding vessel should remain in the breach made, or on the obstacle that had caused a breach in herself, until some information had been obtained as to the damage done. A proposed law of collisions at sea, which he considered should be acted upon by officers in charge of ships, was as follows: (1) Keep your ship in the breach made; (2) keep your ship on the breach maker; (3) strike straight on end if you can; (4) wireless call for assistance; (5) close water-tight doors and ports; (6) passengers and crew to boat quarters. Had these simple rules been observed in the case of the disaster to H.M.S. "Victoria," and had the "Camperdown" reversed her engines to "slow ahead" immediately after impact, and retained that position as long as necessary, he considered this would have saved the "Victoria," as well as her crew. He was of opinion also that the observance of these rules would have mitigated very largely the disaster to the "Titanic."

Mr. W. McLaren spoke in appreciation of the author's suggestions. He considered that, especially in naval disasters, too much importance was attached to the necessity of the men meeting their death courageously, as compared with the adoption of simple methods of averting, or remedying, the effects of such disasters. Mr. G. Shearer thought it impossible to set down hard and fast rules, as everything would depend upon the condition of the sea at the time. The suggestions of Mr. Newall would be very useful in smooth weather, with the exception that the order to close the water-tight doors and ports should, in his opinion, be placed first on the list. He instanced a personal experience of a ship striking the rocks, in which case to have attempted to remain on the breach-maker would have been disastrous. Mr. E. W. Ross pointed out that in the majority of instances of collisions it would be practically impossible to "strike straight on end," as strenuous efforts were usually made to avert the object, and a glancing blow was the result. He very much questioned whether the rule suggested by the author as to remaining on the breach-maker would have availed any good in the case of the "Titanic," especially as it was open to doubt whether the disaster was due to a shelving piece of ice or to a projecting spur. Mr. G. W. Roger cited instances to show that, while in one case to remain in the breach made proved effective, in another such a course would have been disastrous. The Chairman remarked upon the special difficulties met with in the case of icebergs. Some of the laws suggested by Mr. Newall were already unwritten laws when the circumstances were favourable, but he did not think the observance of such recommendations could or would be made binding.

Mr. Newall, in replying, said the closing of the water-tight doors and ports depended a good deal upon the rules he had placed first on the list being observed. He quite agreed that it would not be possible to lay down hard and fast rules for all circumstances, but he suggested that the rules should be recognised as applicable in the majority of cases.

CONDENSER DESIGN.

In the course of the discussion on the paper entitled "Development of Auxiliary Units between Exhaust Pipe and Boiler," read by Mr. William Weir at a meeting of the Institution of Engineers and Shipbuilders in Scotland, and reproduced recently in our columns, Mr. D. B. Morison related his experience in condenser design. It was, he said, in 1904 that he first commenced the research on condensers, which had since been so generally fruitful in its effects. Those interested in the subject would find instructive data in a paper read by Prof. Weighton before the Institution of Naval Architects in 1906, and also in a paper read by himself before the same institution in 1908. The research therein described was very elaborate, besides being particularly costly, but his desire then, as now, was to lay bare his experiences in the hope that they might in some measure contribute to engineering progress. Morison's specification, No. 15,759, of 1904, read as follows: "The uniform flow of the steam and air over the entire tube surface has the important practical effects of increasing the heat transmitting efficiency to such surface, and also of assisting and maintaining an even flow of air towards the final outlet, thereby so minimising the local stagnation of flow, or the local accumulation of air, as to increase the vacuum efficiency by enabling the air pump to improve the vacuum."



Fig. 1.

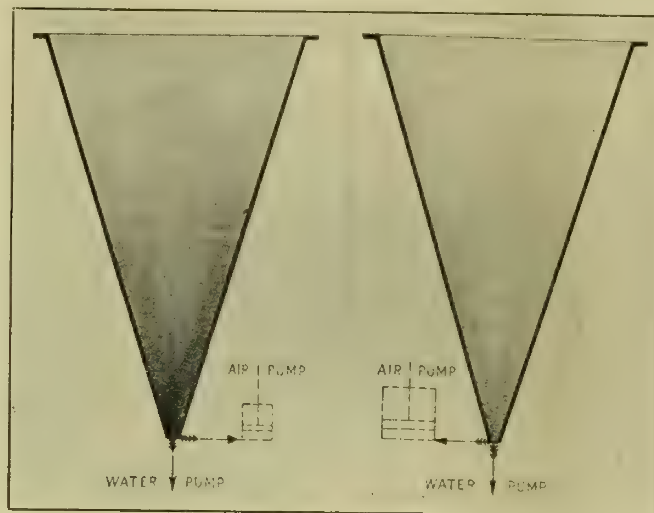


Fig. 2.

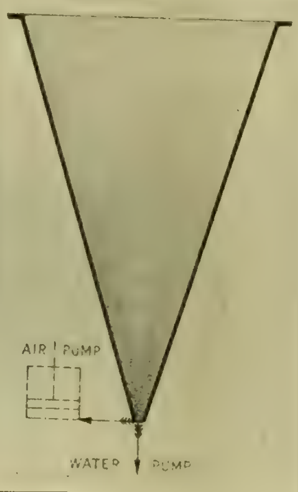


Fig. 3.

That was to say, he started off by establishing initial uniformity of exhaust distribution over the tubes throughout their whole length, and whilst maintaining such uniformity over the entire condensing surface, he maintained at the same time a continuity of flow through a passage of decreasing area from the exhaust inlet to the air outlet. In order to lengthen the path of vapour flow in his original small condenser, he cut a wedge into three pieces and set one above the other. This small condenser he presented to the Armstrong College, and Prof. Weighton's experiments with it definitely established the correctness of the principles, as might be seen by reference to his paper, which was generally conceded to be the most valuable report on surface condenser efficiency ever published.

By subsequent experience with large condensers, he found that conditions enabled the wedge shape to be maintained linearly by light guide plates, which not only cheapened the construction and lessened the weight of large condensers, but in condensers of any size facilitated the employment of wedges of the proportions which had been found by exhaustive tests to give the highest efficiency. If no air were present in condensers the problem of surface condensation would be simplified, as no air pump would be required, but in practice the crucial problem in the attainment of high vacuum was how best to treat the small quantity of air which normally entered the condenser with the steam, and at the same time to make provision for dealing with the much larger quantities which resulted from accidental and inevitable leakage in the vacuum system. As the result of much investigation over many years, he was about to submit a theory whereby a solution might, he thought, be found along the simple lines of elementary first principles.

In 1905, Mr. J. A. Smith, of Australia, carried out some very valuable experiments to determine the effect of air on heat transmission through a condenser tube. He found, broadly, as follows: That the presence of air in quantities which might have been deemed insignificant might, in fact, become the factor limiting the efficiency of a whole steam plant. For instance, air equal in pressure to only $\frac{1}{20}$ of an inch by the mercury gauge would, at 90° Fah., reduce thermal transmission some 25 per cent., whilst $\frac{3}{20}$ of an inch would lower it about one-half. The experiment further demonstrated that in a condenser dealing with steam at 90° Fah. smothered with air, at a partial pressure of $\frac{3}{10}$ of an inch, the cooling surface would have to be $2\frac{1}{4}$ times greater than if dealing with airless water vapour at the same temperature. The feature of interest in these experiments was the extraordinary degrading effect which a film of air of minute thinness had on the heat transmission of a condenser tube. At the other extreme they knew that when air was present in large quantities in a condenser, the lowermost tubes might become so air drowned as to be quite incapable of condensing any appreciable vapour. It was also further established that air was heavier than water vapour, and consequently the natural tendency of aerated vapour was to fall and not to rise. This, of course, was apart from all considerations of velocity of entry. Therefore, the first essentials for condenser efficiency were that the weight of air which always remained in a condenser should be reduced to a minimum, and should be so disposed as to cause the least possible resistance to the transmission of heat through the tubes to the circulating water flowing through them. Another essential was that the air particles should not eddy by taking an erratic course in any given horizontal plane, or by making multiple appearances in any plane. In other words, each air particle should take its shortest route from the exhaust inlet to the air outlet, and not linger on the way.

Such a theory at once suggested that exhaust steam should enter a condenser as a uniformly moving column, the sectional area of the column being the plan area of the top row of tubes. If this plan area were continued unchanged, the condenser became a rectangular box, in the middle of the base of which let the air pump suction be placed. Assuming hypothetical stability, the condenser became filled with an infinite number of horizontal superposed films, the top film containing the least amount of air and the bottom film the greatest. The contained air in such a condenser was the sum of the particles in all the films, and as the function of an air pump was to minimise the weight of air which was normally present in a condenser, it was obvious that the lowermost film, which was the film richest in air, should be preferentially and wholly withdrawn by the air pump, and be followed by the entire withdrawal of the superposed film and so on. In such a rectangular box, under such conditions, the air pump would break through several films locally, and by withdrawing a charge less rich in air, and, therefore, inferior, would leave the bulk of the lowermost and densest film undisturbed.

Suppose by some means or other the lowermost film were disposed vertically instead of horizontally, the air pump would then draw not multiple layers from unstable thinness, but one layer from stable depth. The nearest practical approach to this requirement was a wedge section having a very narrow outlet, as in Figs. 1, 2, and 3. Again, suppose another hypothetical condition, viz., that there was no air in the con-

denser Fig. 1, and that the condensate was withdrawn by a water pump. Assuming also that the frictional resistance of the vapour passing over the tubes was nil, then were such conditions possible in practice, the vacuum and the temperature throughout the condenser would be constant. Fig. 2 represented the same condenser under conditions of ordinary practice, viz., with air and air pump. Assuming the air to be shaded as shown, and that the air density was proportionate to the depth of tint. Supposing such a condenser to be working under conditions of vacuum stability and with no eddying anywhere, the shading would then be lightest at the top and darkest at the bottom, the temperature would be highest at the top and lowest at the bottom, and the charge of air withdrawn by the air pump at each stroke would be the densest the condenser contained.

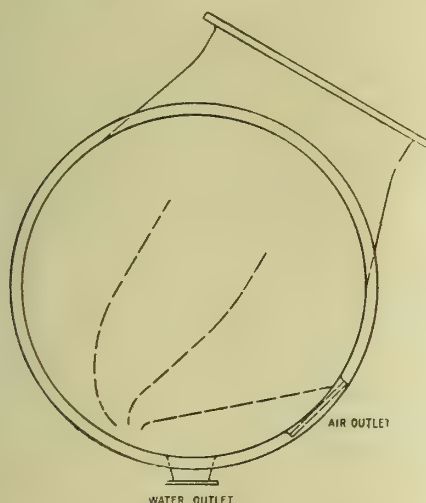


FIG. 4.

Now, supposing in Fig. 3 the conditions were identical with those in Fig. 2 in every respect, except that in Fig. 3 a lighter shade was maintained at the bottom of the condenser, say, for example, a shade corresponding to the shade in the middle of Fig. 2. It ought to be remembered that the quantity of air admitted with the exhaust was precisely the same in both Figs. 2 and 3, but the weight of air which always remained in the condenser in Fig. 3 was less than that which remained in Fig. 2, by the amount below the centre line in Fig. 2. The general technical effect thereby produced was that every single tube in the condenser had been relieved of a definite amount of air insulation, and was, therefore, able to transmit more heat to the condensing water, with the result that the final temperature of the condensing water increased, the condenser cooled, and the vacuum rose. It was the condenser which was primarily responsible for the high vacuum attainable under these conditions, as by means of the wedge the air was arranged in density gradations which reached a maximum at the outlet from the condensing chamber; but the disposition of the gradations at the outlet must be such that a given weight of air presented as small a surface area and as great a depth as the practical requirements of sufficiency of passage would permit. Concurrently, the air pump was enabled to maintain such an air condition within the condenser that the air density at the air outlet was minimised, the air insulation within the condenser was reduced, and the greatest amount of heat was transmitted to the condensing water. It should again be noted that each air pump normally withdrew exactly the same quantity of air per unit of time, viz., the quantity which entered the condenser with the exhaust steam, but in Fig. 4 a less air density was maintained at the air outlet, and, therefore, there was less air insulation within the condenser than in Fig. 3. The relation between a condenser and an air pump might thus be seen. For example, the ability of a condenser to create a very high vacuum might always remain latent if it was worked in conjunction with an inefficient air pump. What was required was such combined unit efficiency which would enable the very highest vacuum to be maintained that the condenser was capable of producing.

The next important consideration was the proportions of the wedges. The thin end presented no difficulty whatever. It should be so narrow that the air formed a strip or plug of such stability that eddying or disturbance was impossible. In practice the width was usually determined by the diameter of one or more tubes with the necessary allowance for the passage of air and condensate. The desideratum at the top of the wedge was to stop eddying. This could best be achieved by arranging the wedges as, for example, in Fig. 4. It would be evident that the often misunderstood problem of intermediate collection of condensate and the consequent influence on its temperature now became very simple. Referring again to Figs. 1, 2, and 3, no air being present in Fig. 1, there was equality in temperature throughout the condenser, and on the formation of drops of condensate they splashed over tubes in their descent, and were alternately cooled by the tubes and heated by the vapour, until on arrival at the bottom they were approximately at the same temperature as that corresponding to the vacuum. In Fig. 2, air being present, the temperature gradually decreased from the top to the bottom, and, therefore, the drops of condensate when falling passed through a cold air zone, with the result that the final temperature was less than that corresponding to the vacuum. The temperature of the condensate relatively to that of the vacuum, therefore, depended on the temperature of the air zone through which it fell, and also on the shape of the condenser.

Almost any condenser lent itself to the intermediate collection of condensate, as some must fall on the sides and thus short circuit the colder air zones. In Fig. 4 the multiple wedge chambers discharged into an air receiver which might or might not be fitted with tubes. For high vacuum, tubes were very valuable, as they enabled the temperature of the air to be brought within a few degrees of that of the condensing water. It would be noted that this effect was initiated in the base of the multiple wedges, where many of the tubes were entirely sheltered from the streams of falling

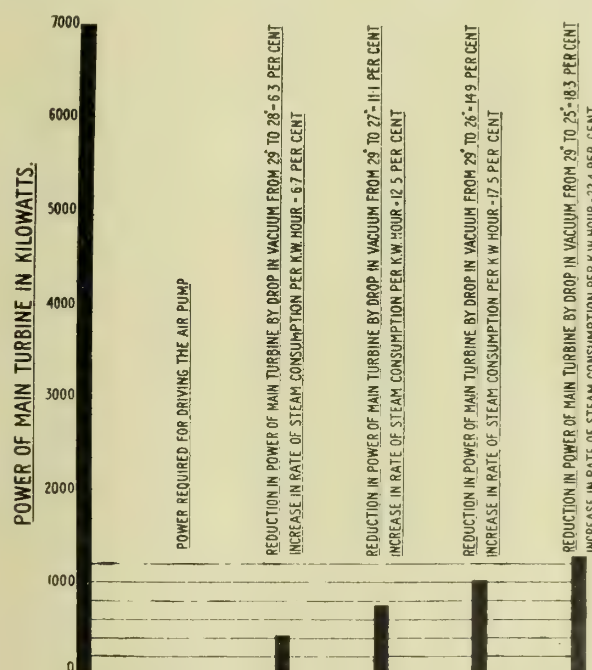


FIG. 5.

condensate, and carried to its logical conclusion in the final air cooling chamber. Having obtained the highest attainable vacuum, what was its value? As would be seen by Fig. 5, in a commercial turbine plant it was represented by increased profit. On a turbine-driven warship it was represented by increased military efficiency. In both it was of supreme importance.

Spanish Steel-making.—The production of steel ingots and casting steel in Spain last year was 322,981 tons. During the past seven years the production has shown a slow but steady progress.

ELECTRIC RESISTANCE WELDING.

A PAPER on "Electric Resistance Welding" was read by Mr. P. Bucher at a meeting of the Manchester section of the Institution of Electrical Engineers, held on the 17th inst. Although the art of welding metals was, he said, undoubtedly very old, the introduction of special apparatus and labour-saving machinery superseding the old method was a quite modern achievement. If the correct interpretation of welding signified the joining of two pieces together so as to form one while hot under pressure, then the only one of these new methods which could rightly be classified under this head was the electric resistance welding. The underlying principle of resistance welding, *i.e.*, the use of very heavy currents, made the necessary machinery heavy, cumbersome, and expensive. The field was therefore not for jobbing work, where arc and hot-flame welding reigned supreme, but repetition work, where it scored immensely by virtue of its simplicity, accuracy, reliability, speed, and economy.

The process was simple. No long tuition was required to make an unskilled labourer proficient in its use. In a good many instances his work was limited to bringing the material to the machine and starting the mechanism, in others to clamp the pieces and let the machine do the rest, but even where he had to do the clamping, the switching on and off of the current, the jumping up and afterwards the releasing of the welded piece and the swaging, he had the joint always in full view and the heat under absolute control. It was accurate. A very high standard was attainable in this respect, for instance, the manufacture of block-chain and printers' chases. It was reliable. As the heat was generated in the piece itself, and was under perfect control, the risk of overheating or underheating, "burning" or "cold shutting," was greatly reduced; also the risk of inclusion of foreign matter, cinders, scale, flux, &c., in the joint, and the importance of this was evident when it was realised that these points were the chief causes of failure in welded joints. It was speedy. Chain links were welded at an average rate of ten to fifteen per minute, or thirty to forty thousand per week. An average week's output of a heavy tyre-welder was 525 tyres, varying in width from 2in. to 9in. A bank of spot-welders worked by boys on miscellaneous hollowware dealt with 120 to 180 gross of articles per machine, corresponding to about 35,000 welds per machine per week. The heat efficiency of a welder was about 75 per cent. It only used current when welding, and very little then. The above-mentioned weekly output of chain, assuming about 3 S.W. gauge, would use from 100 to 130 units. The tyre-welder referred to used according to the supply company's meter 737 units, and a spot-welder on miscellaneous hollow-ware used about 1 to 1·5 units for 1,000 welds.

The various applications of electric welding in commercial practice could be subdivided under the following headings:—

Plain butt-welding, or the welding end-to-end of bars and the like of the same or approximately the same area. Butt-welding was also possible within certain limits if the two areas were dissimilar, and the object was accomplished by letting the larger bar project farther from the clamps than the smaller one in roughly the same proportion as the two areas. A variation of the plain butt-welding was the angle, tee, and mitre welding, which was used on both rectangular bars and various sections of profile iron.

Spot-welding took the place of riveting in that way that only a small percentage of the total area in contact was welded together in circular spots. In the great majority of cases this was done one spot at a time; there were exceptions, however, where the making of two spots at a time meant a considerable saving, either obviating a change in the setting of the electrodes or the use of two machines on one job. Great care must be taken, however, in the setting of the twin electrodes so that both bore with exactly the same pressure on the work, otherwise an unequal flow of current through the two spots and with it unequal heating resulted. A great help in this respect was a spring-compensating device to counteract slight inequalities in the thickness of the material. A development of spot-welding was seam-welding, in which the two sheets were joined together in an uninterrupted lap-weld under one or between two rotating disc electrodes.

The most important question in the whole business was the strength of the weld. Figures from private tests would be very unconvincing, so the author obtained permission from Dr. Stanton of the National Physical Laboratory, to make use of figures obtained in "experiments on the strength and fatigue properties of welded joints in iron and steel," a paper read before the Institution of Civil Engineers by Messrs. Stanton and Pannell. These experiments were made on sample welds prepared by sixteen different engineering firms in the kingdom according to their usual practice, some by hand, some by electric, and some by gas-welding, with the object of comparing the strength and fatigue properties of welds in iron and steel with the corresponding properties of the same unwelded material. The condensed result for tensile strength wsa expressed in percentage of the tensile strength of the unwelded material:—

Hand-welded Iron.	Hand-welded Steel.	Electric-welded Iron.	Electric-welded Steel.
Mean of 24 tests 89·3	Mean of 21 tests 81·6	Mean of 7 tests 89·2	Mean of 8 tests 93·4

In the same way for fatigue properties:—

Hand-welded Iron.	Hand-welded Steel.	Electric-welded Iron.	Electric-welded Steel.
Mean of 21 tests 97·6	Mean of 28 tests 78·4	Mean of 5 tests 92·6	Mean of 12 tests 87·0

As proof of the strength of spot-welds, the following test-certificate from Lloyd's Proving House at Netherton was quoted: "I have tested to destruction two mild steel clips electrically spot-welded, with the following results, viz.: No. 1 Clip with single butt-strap broke at 11·025 tons (clear of welded joint), being 29·01 tons per square inch of section. No. 2 Clip with double butt-strap broke at 11·767 tons (clear of welded joint), being 31·01 tons per square inch of section. The weld in each case does not appear to have been disturbed." These figures proved that in the electric resistance method the manufacturer had an entirely reliable way at his disposal to effect a weld where such was required. There were no independent figures available concerning electric welds in metals other than iron and steel. They were, however, in daily extended use in brass and copper wire mills, for joining up rods and slottings, which afterwards passed through the drawing dies.

Of the metals that could be welded by electricity iron and mild steel came first. High carbon steel could be welded up to about 0·8 per cent. carbon, but the results were not so satisfactory as in mild steel, neither as regarded the tensile nor the torsional strength. When high carbon wire was welded the heat of the weld was a very short one, and the bulk of the adjoining cold metal seemed to have a quenching effect on the steel, so that the wire when taken from the machine was glass-hard at the joint and snapped on the slightest effort. To overcome this the wire must be locally annealed—for preference in the welder itself—and this heat treatment weakened the wire for the length to which it had been applied as compared with the rest of it. Generally speaking, the strength of a welded high carbon wire was about 60 to 70 per cent. of the unwelded wire. After iron and steel came the non-ferrous metals, chief amongst which were copper and its alloys. Pure copper welded quite satisfactorily, and so did most of the brasses unless the percentage of zinc in them was too high, when the weld became brittle and would not draw. Nickel and most of its alloys also welded very well, as did aluminium, silver, gold, platinum, and iridium. These remarks applied, however, only to butt-welding, as only iron and mild steel lent themselves to spot-welding in a satisfactory manner. Brass and aluminium could be spot-welded, but the process was not very reliable nor economical on account of the heavy current required.

Serious Lift Accident.—A lift accident which resulted in two men being more or less seriously injured occurred at Messrs. Wathes, Holloway Head, Birmingham, on the 19th inst. Three men were going down in the lift when the rope broke, with the result that the lift crashed to the bottom of the well.

STANDARD CROSS-SECTIONS AND SYMBOLS.

SOME little time ago a committee, comprising Mr. H. de B. Parsons (chairman), Mr. F. der Furman, Mr. A. E. Norton, Mr. Bradley Stoughton, and Mr. John W. Upp, was appointed by the American Society of Mechanical Engineers to consider the question of standard cross-sections and symbols used on mechanical drawings. This committee have now presented their final report, which is as follows :—

We strongly believe that there should be recognition of a standard method of showing materials in cross-section. There are many advantages in encouraging the use of standard cross-sections and symbols. It is as easy to draw an adapted design to represent a specific material as to draw any other. It makes mechanical drawings easier to read and understand, and diminishes the danger of interpreting their meaning wrongly.

We do not believe it wise to complicate the matter by adopting too many standard cross-sectionings or symbols. We believe it would be best to have standard cross-sections for the most commonly used materials, and these should be of such a character

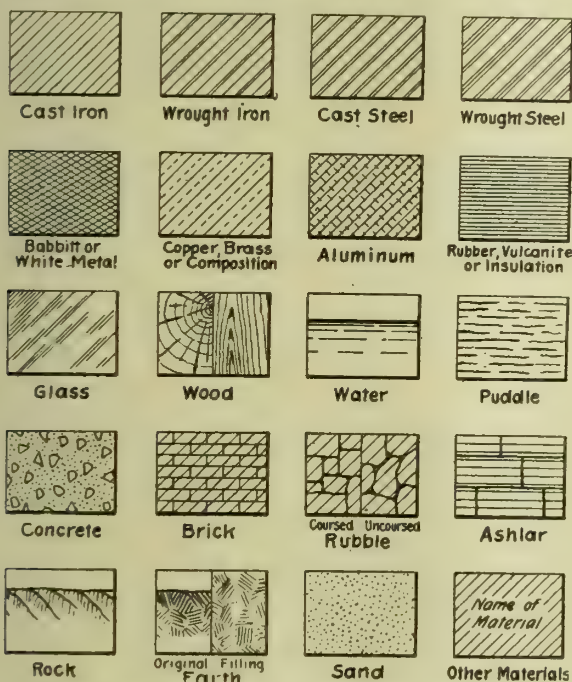


FIG. 1.—RECOMMENDED STANDARD CROSS-SECTIONS.

as to permit of sub-division if found desirable. To this end we propose the use of standard cross-sections to represent nineteen materials as shown on Fig. 1. To facilitate the drawing of cross-sections, the committee have used the same thickness for all lines made with the drawing pen. On some drawings it may be desired to specify a material other than those mentioned above, or some particular kind of material which the generic names on Fig. 1 would not clearly indicate. To cover this contingency, we recommend writing the name of such material on the section and cross-hatching the section, as shown on Fig. 1 under the title " Other Materials."

We recommend that sub-divisions of any of the materials shown generically on Fig. 1 should be made by taking one of these standard cross-sections as a basis and making minor changes, but maintaining the general characteristics ; or by writing on the standard section the name of the material. To illustrate, the committee have subdivided concrete into concrete blocks, cyclopean concrete, and reinforced concrete, as shown on Fig. 2, and also wrought steel into nickel, chrome, and vanadium steels.

We urge the Society to adopt standard cross-sections. Such standard cross-sections should be printed in a suitable form for hanging on walls of draughting rooms of engineers, architects, and educational institutions, so as to encourage their universal use. Before closing, we acknowledge the valued assistance of Mr. D. C. Johnson in obtaining data for the committee and extend our thanks to the many manufacturing establishments, government departments, and individuals who have sent us such standards as are in use by them.

WATER-TIGHT SUB-DIVISION OF SHIPS.

MR. J. BRUHN, D.Sc., director of the Norsk Veritas, read a paper on the " Water-tight Sub-division of Ships," at a meeting of the Institution of Engineers and Shipbuilders in Scotland, held in Glasgow on the 17th inst. Mr. Bruhn, in the course of his paper, said that in his opinion it would be unjustifiable and wrong to consider the accident to the " Titanic " a standard one, in the sense that sufficient sub-division ought now to be demanded to enable a ship to float with as extensive damage as that which the " Titanic " received. The circumstances of the accident to the " Titanic," particularly the speed of the vessel and the known proximity of ice, were such that they ought not to be looked upon as circumstances which might reasonably be expected to be met with in the future, and which ought therefore to be provided against in arranging a vessel's sub-division. It was impossible, even with the most extensive experience at hand, to fix definitely the standard of sub-division which would guarantee safety. He thought it was desirable that this should be stated clearly, as the general public was often apt to look on such questions as being simply little mathematical problems to be readily and promptly solved by experts if they knew their business. One of the most difficult questions in connection with the sub-division of ships, Mr. Bruhn continued, was the

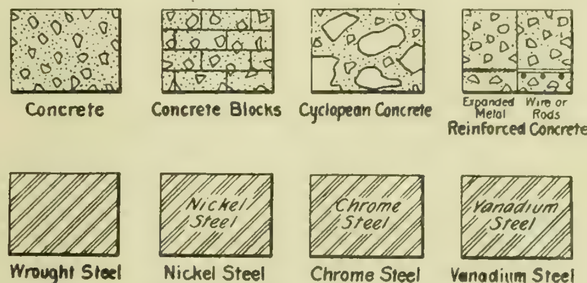


FIG. 2. TYPICAL SUB-DIVISIONS.

fixing of the particular sizes of vessels in which sub-division was to be increased or additional bulkheads fitted. It would appear that public opinion was that absolute safety could be demanded and supplied. That, of course, was impracticable, and there was no reason why such a demand should be made in connection with the transport of passengers at sea when it was not made where the transport took place by rail or road. To make the small vessel as secure against foundering as the large one would lead obviously to the extinction of the former, and that would not be for the benefit of the community at large. He thought it was clear that for the smaller passenger steamers the present practice of fitting peak and machinery space bulkheads must be considered sufficient and reasonable in view of the rapidity with which all passengers might be transferred to the lifeboats in cases of accidents. A length of 250ft. might be fixed as a reasonable maximum for this class of sea-going steamers. For vessels from 250ft. to 300ft. in length perhaps one or, where the engines were fitted aft, two bulkheads ought to be fitted between the machinery space and the forepeak. For vessels over 300ft. the length of hold should be limited. He suggested the limits which might be imposed for different sizes of vessels. A definite rule, he added, for the determination of the number of bulkheads was desirable. If a sub-division rule was made international it would be the same for all, and it could not then be considered a serious hardship to any individual shipowner. Sub-division ought to be made compulsory independently of the life-saving appliances provided.

Post-graduate Scholarship in Naval Architecture, 1913.— The Royal Commissioners of the 1851 Exhibition, acting on the recommendation of the Council of the Institution of Naval Architects, have appointed Mr. P. Y. Brimblecombe, late of Armstrong College, Newcastle-on-Tyne, to the above scholarship, of the value of £200 per annum and tenable for two years, for the purpose of carrying out a course of research work in naval architecture at the Armstrong College.

EARTHED VERSUS UNEARTHED NEUTRALS ON ALTERNATING-CURRENT SYSTEMS.*

BY J. S. PECK.

THE questions where, when, and how should the neutral point or points of an alternating-current system be earthed are highly controversial ones, and though they have been discussed a number of times before the technical societies, there are still wide differences of opinion among operating engineers as to the proper course to follow under different conditions. While it is difficult to give general rules concerning all cases, there are certain conditions where the proper course to follow seems clear, and it is intended in this paper to discuss the various questions involved, and to show why under some conditions of operation it is becoming general practice to earth the neutral, while under others it may be advisable to operate with the neutral unearthed. Three classes of apparatus or systems will be considered : (1) Generators, (2) high-voltage transmission circuits, (3) low-voltage distribution circuits.

Before considering these three classes separately, the general advantages and disadvantages of the earthed neutral which are common to them all will be considered. While several advantages may be claimed for the earthed neutral, there are but two which are really of any great value. These are : (*a*) The limiting of the voltage between line wires and earth ; (*b*) the possibility of cutting

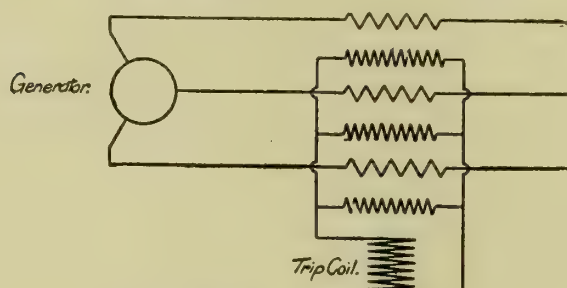


FIG. 1.—BALANCED PROTECTIVE GEAR.

off any wire or feeder in the event of an earth upon it. The chief objection to earthing is the fact that the system cannot be operated with an earth on any line wire.

It is well known that in an unearthed 3-phase system, where the impedance of each phase to earth is equal, each of the three conductors assumes a potential above earth equal to 58 per cent. of the voltage between wires while the neutral point is at earth potential, but any difference in the impedance causes the potential of the neutral point to shift, bringing the phase having least impedance nearer to earth potential and raising the others to a potential correspondingly higher above earth. When one phase is earthed, it assumes earth potential, and the other phases reach full-line potential above earth. When the potential of each phase to earth is the same, the charging current to earth will be equal in all phases, but when one phase is earthed the charging current to earth is increased by 73 per cent. in both of the unearthed phases, and all of this current will return to the generator through the earthed phase and will pass into the faulty wire at the earthed point. Earthing the neutral means that this point is fixed at earth potential, and the three-line wires are fixed at a potential 58 per cent. above earth. If the neutral point is earthed through a resistance and one phase is earthed, current flows through the neutral resistance, and the drop across this resistance measures the voltage between the neutral point and earth, so that the neutral point is not fixed definitely but depends upon the amount of resistance and the current flowing through it. Thus the conditions are intermediate between those with the unearthed neutral and with the neutral solidly connected.

With the earthed neutral very simple and reliable apparatus can be provided, which will cut out any feeder in case an earth occurs upon it. This apparatus may be of the Merz-Price balanced protective type, or it may be of that type which is based upon the principle that the resultant current in a 3-phase circuit is zero. Fig. 1 shows a well-known arrangement of this kind. It is evident that under normal conditions the resultant current in the secondaries of the three transformers is zero, therefore no current can flow through the trip coil ; but should an earth occur on one of the wires, the circuits will be unbalanced and current will flow through the trip coil. This apparatus may be adjusted to work on a very small earth current. Still another possibility is to put a trip coil in series with the earth connection, but this arrangement is not so satisfactory as those previously mentioned, in that it does not discriminate as to the feeder to be cut off.

Where a large cable network is supplied from common bus-bars the arrangement shown in Fig. 1 may work satisfactorily without the neutral point being earthed. The reason for this is as follows: In the event of an earth on any wire, the charging current to earth on all of the cables on the system will be returned to the bus-bars through the wire which is earthed. Therefore the current balance on the earthed feeder will be upset and the circuit breaker operated. This arrangement is, however, limited in its application, and is not so positive as when there is a current flow between earth and generator neutral.

GENERATORS.

All modern 3-phase generators are insulated to stand operation without the neutral being earthed, so that no consideration of reduced first cost due to limiting the voltage to earth by earthing the neutral need enter the problem. Also the question of risk of breakdown with earthed or unearthed neutrals may also be practically neglected. When deciding upon the advisability or otherwise of earthing the neutral of a generator, consideration must be given to the service for which it is to be used. Three classes of service will be considered : (*a*) Generator supplying network of underground cables ; (*b*) generator supplying overhead transmission circuits without transformers ; (*c*) generator supplying overhead transmission line through step-up transformers.

In case (*a*) an earth on any phase of a cable is almost certain to develop into a short circuit between phases, and on a large system the result of a short circuit on a cable is usually to burn off a section of the cable, perhaps to damage adjacent cables, and sometimes to set up surges which may cause serious breakdowns elsewhere on the system. Since the majority of breakdowns on cables are to earth, it is therefore extremely desirable that a cable be cut off as soon as an earth develops, and as this can be done quickly and with certainty where the generator neutral is earthed, it is becoming general practice to do this in all stations of this class. Thus practically the only question to consider is whether the neutral should be earthed solidly or through a resistance, and, where there are several generators in parallel, how many of them should be earthed. The only object in inserting resistance between generator neutral and earth is to limit the rush of current which occurs whenever there is an earth on the system. If balanced protective apparatus is used, similar to that shown in Fig. 1, the resistance may be made so high as to keep down the current rush to a comparatively low value, because the protective apparatus may be set to operate with a very small unbalancing in current ; but where plain overload protection is used—and this applies to the majority of cases—the resistance should be low enough to pass sufficient current to trip the breakers on the largest feeder, but high enough to prevent damage to generator windings, and, if possible, to prevent serious burning at the point of accidental earth. In calculating this resistance, allowance should be made for the drop in voltage on the generator due to the load on one phase, also for the resistances in neutral earth connection in the feeder and at the point of accidental earth. In designing the resistance, ample heat capacity should be allowed, for the circuit breakers may stick, or there may be at least temporarily a fairly high resistance at the point of accidental earth which will prevent the circuit breaker from opening immediately, and so give time for the resistance to reach a high temperature.

In general, earthing resistances are built up of cast-iron grids mounted on porcelain insulators, and should be located in a fireproof compartment. They are usually designed to have sufficient heat capacity so that full star voltage may be maintained across them for at least 15 seconds without a temperature rise of approximately 300° C. being exceeded. The ohmic value of the resistance is determined by the current required to trip the breakers on the largest feeder.

Where it is desired to earth through a resistance, and two or more generators are operated in parallel, the simplest and best method in so far as earthing is concerned is to connect the neutral

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of all the generators to a common bus-bar which is earthed through a suitable resistance. Then, regardless of the number of generators, the value of the earth resistance will always be the same. With this arrangement switches must always be provided between each generator and the neutral bus-bar, otherwise a generator disconnected from the main bus and shut down may be raised to a dangerous potential above earth in case of an earth on any feeder. The objection to this method of connection is that in certain cases very heavy currents may circulate through the neutral connections and generator windings, and while the deleterious effect of this current has been greatly overestimated, it appears that in certain cases it has been almost impossible to operate with the neutrals connected solidly together. When the waveforms of the different machines are exactly the same, no current can flow through the neutral connections, but when the waveforms are different and there is a third (or multiple of three) harmonic present, current will flow through the neutral connection, the amount of which will depend upon the value of the third harmonic, the displacement angle, and upon the impedance which the generator offers to this current of triple frequency. Machines which at no load give no circulating current may show heavy circulating currents as the load comes on, or vice versâ. The amount of the circulating current also depends upon the adjustment of the field current of the different machines, and upon the angular variation in speed of the prime movers.

In certain abnormal cases the current in the neutral may amount to the full-load current of one generator or even more. It should be noted, however, that the neutral current divides equally among the three phases of the generator, so that full-load current in the neutral is equivalent to only 33 per cent. full-load current in the windings of the generator, and since the heating in the windings is equal to the sum of the squares of the main and circulating currents, the resultant heating is increased by only 11 per cent.—not a serious amount even with this very high value of circulating current. With 30 per cent. of full-load current in the neutral the resultant heating in the generator is increased by only 1 per cent. at full load and is quite negligible. It would seem advisable, therefore, to try connecting the generator neutrals solidly together, especially in the case of turbo-generators, where there is no angular variation in speed, and therefore less chance of circulating currents. Should satisfactory operation be impossible, then only one generator should be connected to the neutral bus, or resistance may be inserted between each generator and the neutral bus.

Of the three methods, that of connecting the neutrals solidly together is undoubtedly the simplest and best, while the method of operating with an earth on only one generator comes next in simplicity. The switching on and off of the different generators to the neutral bus may be done automatically, as at the London County Council Greenwich generating station, or it may be done by hand. While the latter method depends upon the memory of the station attendant, or upon the systematic operation of the station, the fact that the attendant may forget to connect a machine to the neutral bus-bar does not mean disaster, as it is only in case of a cable breakdown that trouble may occur, and it must be remembered that many stations are operating successfully with an unearthed neutral. Where resistances are used between each generator and the neutral bus, a very considerable expense is involved in providing these resistances, and it is often difficult to find room in the station to accommodate them; also the resistance in the earth circuit is much less when there are several generators in parallel than when only one is in use.

(*b*) *Generators supplying Overhead Transmission Line without Step-up Transformers.*—In this case there are usually a comparatively small number of transmission lines, and an earth on one wire is not likely to cause a short circuit between wires, so that with an unearthed neutral it is quite possible to run for a long period with one wire earthed. If there are not sufficient feeders to all distributing centres to make it possible to cut out a defective one and deliver full load over the others, the possibility of being able to operate with one wire earthed may be sufficient far to outweigh the only practical advantage gained by earthing the neutral, which is the ability quickly to cut off a feeder in the event of an earth upon one wire. Limiting the voltage between each wire and neutral, which can be done by earthing the neutral, is of very little importance, since the voltage is in no case very high, and the generators and the line must be insulated to withstand strains set up by lightning discharges and other abnormal conditions. It would appear, therefore, that in the majority of cases the weight of the arguments are in favour of operating with the generator neutrals unearthed.

(*c*) *Generators supplying Transformers which Step Up to a very High Voltage for Long-distance Transmission.* In this case there are conditions involved which make it extremely desirable to earth the neutral or else to earth the low-tension side of the transformers. If one terminal of the high-tension side of a single-phase transformer be connected to a high-tension line, and the low tension be open-circuited, the high-tension winding assumes a potential above earth equal to that of the line to which it is connected. The high-tension winding then acts as one plate of a condenser, with the low tension and core as the other plates. The low-tension winding also has static capacity to the iron, and it will therefore assume a potential above earth the value of which will depend upon the relation between its capacity to the high-tension winding and its capacity to earth.

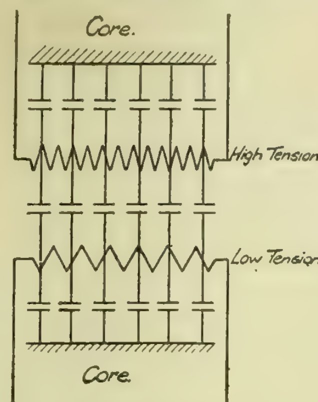


FIG. 2.—ELECTROSTATIC CAPACITY BETWEEN COILS AND BETWEEN COILS AND CORE OF A TRANSFORMER.

In practice it may easily assume one-half the potential of the high-tension winding (see Fig. 2).

If—

K = capacity between high tension and low tension.
K_1 = capacity between low tension and core.
V = voltage of high-tension line.
V_1 = potential of low-tension winding above earth.

$$V_1 = V \times \frac{K}{K_1}$$

If both terminals of the high-tension winding are connected to the high-tension lines, the resultant potential of this winding above earth will be zero, and the resultant potential of the low-tension winding above earth will also be zero. If, therefore, one terminal of a transformer be connected to or disconnected from a line before the other, the low-tension winding during this period may assume a very high potential above earth and its insulation be broken down to earth. When the low-tension winding is connected to a generator, the generator winding also has capacity to earth, so that the capacity of the low-tension winding to earth is increased by this amount and its voltage correspondingly reduced. If the capacity of the generator winding to earth = K_2, then the voltage of the low-tension circuit above earth $V \times \frac{K}{K_1 \times K_2}$. Thus, while the voltage is reduced by connecting the transformer and generator windings together, it may still be dangerously high. When both terminals of the high-tension winding are connected to the line and one wire is earthed, the resultant voltage of the high-tension winding above earth will be $V/2$, and that of the low-tension winding will be one-half as great as before, but may still be dangerously high.

In the case of a 3-phase transformer the conditions are much the same as described above for a single-phase transformer. If one terminal of the transformer is connected to the line, the whole of the high-tension windings will be raised to full-line potential above earth, and the low-tension winding will be raised to a correspondingly high value. If the three terminals of the high-tension winding are connected to the line and one line wire be earthed, the resultant potential of the high-tension winding will be 58 per cent. of the line voltage above earth, while the low tension will be 58 per cent. of its former value above earth.

It is evident that when the neutral of the high-tension system is unearthed there are several possibilities of obtaining a high voltage on the generator windings, viz., in the case of an earth on one high-tension wire, or in the case of the switches in the three phases not operating simultaneously. It is not necessary that a line wire should be permanently earthed in order to raise the voltage on the low-tension circuit, as a discharge over a

lightning arrester may so disturb the static balance of the system as to produce a high potential on the low-tension winding.

A case is on record where several generators in parallel were supplying a very high-voltage line through step-up transformers. The neutral point of the generators was unearthed. The lightning arresters on one high-tension phase broke down and the generator windings were raised to a high potential. One generator broke down, and the attendant, seeing smoke, cut it off the bus-bars. A second machine immediately broke down, and was in turn cut off. This was repeated until nearly all the generators in the station were broken down. The attendant then cut off the excitation. Had the neutral point of the generators or that of the high-tension side of the transformers been earthed, the trouble could not have occurred in the generator circuit. There is, however, a chance of similar trouble even when the high-tension neutral is earthed, provided the generator neutral is unearthed. This occurs when the insulation between the high and low tension windings of the transformer breaks down at one point. The low-tension winding then assumes the potential of the high-tension winding at the point of connection, and a breakdown on the low-tension system is almost certain to follow.

With electrolytic lightning arresters it is necessary to connect the aluminium plates to the lines at frequent intervals in order to preserve the film on the plates. These plates have a high electrostatic capacity, and a considerable charging current flows through the arrester while it is connected to the line. It has been found on one system that when the arresters are being charged, disturbances are set up on the system and breakdowns have occurred on secondary circuits. It is quite possible that this trouble is due to the static unbalancing of the high-tension circuits, which in turn raises the secondary circuits to a high potential above earth.

Where it is considered undesirable to have a direct connection between low-tension windings and earth, a spark-gap may be placed in the circuit and set to break down at a pressure slightly above the normal voltage of the winding above earth.

Another method of protecting the low-tension system in the case of breakdown between the windings of the transformer is the use of earth shields between primary and secondary windings. This system was at one time in general use in this country, but it is now scarcely ever called for. The objections to it are : (*a*) Increased transformer cost ; (*b*) increased risk of transformer breakdown ; (*c*) no protection when breakdown is between leads or anywhere except between transformer coils ; (*d*) the danger that earth shields may become displaced ; (*e*) the leads connecting earth shields to core may be broken due to vibration or to settling of core and coils, or they may be burned off due to heavy charging current which may flow over them ; (*f*) part of earth shield in the neighbourhood of fault may be burned away and leave primary and secondary windings connected together with no earth on the system.

While it may be argued that many of these difficulties are due to defective manufacture, and should not occur provided proper precautions are taken, there is always the possibility that they may occur, and the practical impossibility of inspecting the earth shields after the coils are assembled makes it almost impossible to determine their condition. Thus in the case of generators supplying a high-tension transmission line through transformers, it is highly desirable to earth the neutral point of the generators, and preferably through a rather low resistance. If it is not desired to connect permanently to earth, then a spark-gap should be used in the earth connection.

High-voltage Transmission Circuits.

The arguments in favour of earthing the neutral in the case of high-voltage transmission circuits are : (*a*) The possibility of cutting off the circuit in case of an accidental earth on any wire ; (*b*) reduced cost of transformers and of line insulators due to limiting the voltage above earth to 58 per cent. of line voltage ; (*c*) reduced cost and closer possible setting of lightning arresters ; (*d*) the possibility of using the earth as a conductor in the event of one line wire being disabled. This requires an earth at both ends of the line. The argument against earthing the neutral is that an earth on one wire makes it impossible to transmit over the circuit.

(*a*) Whether there is any advantage in being able to cut off a circuit in the event of an earth on one wire depends upon the number of circuits available. In general, there are seldom more than two circuits to any sub-station, and often there is but one, so that cases may often arise where, to keep up the supply, it will be absolutely necessary to operate with one wire earthed. This method of operation would be impossible with an earthed neutral. Also an earth on one wire is not likely to develop into a short circuit between phases, so that there is no particular need for cutting off the earthed circuit.

(*b*) The higher the voltage of the transmission the greater will be the saving in first cost made by insulating the transformer for 58 per cent. of the line voltage and by using line insulators for a corresponding voltage ; but in general it is bad practice to adopt this expedient, for it may prove impossible to operate continuously with an earthed neutral, due to disturbances on adjacent telephone circuits which may occur under certain abnormal conditions, and in the event of an earth on one wire it may be essential to remove the neutral connection and operate with one wire earthed. In general it is poor economy to cut down insulation on either lines or transformers.

(*c*) If the system may sometimes be operated without earthed neutral the lightning arrester equipment must be suitable for this condition, so that there is no saving in first cost ; but as long as the system is operating properly with earthed neutral the arresters may certainly be set for lower discharge values than when the system is unearthed.

(*d*) In the event of one wire on an earthed system going to earth, it would still be possible to transmit approximately two-thirds the full amount of power over the two remaining wires, provided the neutral points at both ends of the line were solidly earthed and one line with its corresponding transformers cut out of circuit. In this case the earth would carry full-line current, and in very few places would this be allowed on account of disturbances to neighbouring circuits.

The neutral point of a high-tension system can be obtained only by connecting the high-tension windings of the transformers in star, or by the use of an auto-transformer, and this latter method is seldom if ever used. If the high-tension windings are connected in star, then damage to one transformer disables the whole group, while with the delta connection on both windings one transformer of the group may be cut out and approximately two-thirds the capacity supplied from the remaining transformers. (This does not hold in the case of 3-phase core-type transformers, but is true for single-phase and 3-phase shell-type transformers.)

The conclusions to be drawn from the above are that in the great majority of cases continuity of service will demand that the system be operated with an unearthed neutral, and that in general the transformers should be connected in delta on both high-tension and low-tension windings.

Distribution Circuits.

When it comes to a study of the question of low-tension distribution circuits, the majority of the arguments presented above will apply here also, but there enters one other consideration, *i.e.*, the danger to human life. If the neutral point of, say, a 500-volt system is earthed, then the maximum potential above earth which any point of the system can reach is 290 volts. If the system is supplied from a 500-volt geneartor, the difference between a 500-volt and a 290-volt shock may mean the difference between life and death, or it may not, and there is certainly greater risk of shock from a system which is permanently earthed than from one which is earthed only occasionally. The higher the voltage of the generator the less will be the value of the earthed neutral in preventing danger to life due to reducing the voltage to earth.

When the distribution circuits are supplied through step-down transformers, there is always the possibility that the low-tension circuits may be raised to a very high potential, either through an earth on one wire of the high-tension system, or through a connection between high tension and low tension inside the transformer. In the former case there is a great danger to low-tension insulation, and in the latter there is danger to life as well as to insulation. Thus, where the distribution circuit is supplied direct from a generator, the advantages of the earthed neutral are the ability quickly to cut off a defective circuit and a possible reduction in risk to life, due to lower maximum voltage

to earth; but where the circuit is supplied through step-down transformers from a high-voltage line, there is danger to life and apparatus if the neutral is unearthed. Where a single-phase circuit is supplied from a single-phase transformer, the low-tension winding should be earthed, preferably at the middle point of the winding, but it is better to earth one line wire than to leave the system unearthed.

CONCLUSIONS.

Generators.—When generators supply a system of underground cables, the neutral should be earthed through a resistance. This makes it possible to isolate a cable in the event of an earth on any phase before such an earth develops into a short circuit.

When generators supply overhead circuits, it is a question of balancing continuity of service against the ability to cut off a feeder in case of an earth upon one wire. If there are comparatively few feeders, and these of large capacity, each case must be considered individually.

When a generator supplies transmission lines through step-up transformers, the neutral should always be earthed or connected to earth through a spark-gap, otherwise the generator windings may be raised to abnormally high potential above earth. The neutral may be earthed direct, though a comparatively low resistance will usually be preferred.

High-voltage Overhead Transmission Lines.—In this case the number of circuits supplying any particular district is ordinarily very small, and as an earth on any one wire is not likely to develop into a short circuit between phases, considerations of continuity of service will usually determine that the high-tension system should be run without an earthed neutral and with both windings of the transformers connected in delta.

Distribution Circuits.—When the working circuits are supplied direct from a low-voltage generator, the advantage in earthing the neutral is the possibility of cutting off immediately any defective feeder, and when the necessary apparatus is provided for this purpose earthing will in general be preferred. When the working circuit is supplied from a transformer stepping down from a high-voltage line, the neutral should always be earthed.

REMOVAL OF PHOSPHORUS BY ELECTRIC HEATING.*

BY ALBERT E. GREENE.

PROCESSES for the removal of phosphorus from iron or steel are steadily assuming greater importance in view of the abundance of high phosphorus iron ore and the diminishing supply of pure ore. In the present processes of removing phosphorus by the basic open-hearth or basic Bessemer, or even by electric processes, complete control over the metallurgical conditions is either impossible or has not yet been realised. The removal of phosphorus has so long been accomplished along certain well-defined lines that when the electric furnace made its appearance metallurgists adhered to the same old reactions used in the older processes, and failed to appreciate and take advantage of the new forces at their disposal. It is one object of this paper to set forth more clearly the metallurgical reactions by which phosphorus can be removed from iron and to show the necessity of controlling the conditions and particularly the temperature by means other than combustion in the furnace chamber.

Invariably, the commercial removal of phosphorus has been accomplished by oxidation. The reactions involved in oxidation of phosphorus in general consist first of the formation of P_2O_5, and second, the combination of this oxide with lime, forming calcium phosphate which is held in a slag high in oxide of iron. In the present-used processes, the phosphorus is never removed without the assistance or presence of considerable quantities of oxide of iron. The oxygen for removal of phosphorus in the basic open-hearth process comes largely through the medium of oxide of iron and furnace gases, but not from lime, and the lime itself cannot prevent the reduction of phosphorus back into the metal out of slags from which oxide of the iron is largely reduced, and likewise in the basic Bessemer process, although here the oxygen comes originally from air, yet oxide of iron formed in the blow is the essential carrier of oxygen.

* Paper presented at the Cleveland meeting of the American Institute of Mining Engineers.

Among the more important metallurgical conditions which control the reactions of phosphorus are the temperature, the presence of oxidising agents or reducing agents, or both, and the intensity of the resulting oxidising or reducing conditions, or, in other words, the equilibrium conditions governing the reactions involving oxygen; the influence of slags, including the influence of oxides therein having affinity for oxide of phosphorus, or other phosphorus compounds, the solubility in the slag of such phosphorus compounds, the presence of oxide of like chemical nature to phosphorus oxide and tending to displace it; and the affinity of the reduced metal for phosphorus. In processes where the heat is supplied by combustion it is not possible to maintain complete control over all the above conditions. In the open-hearth furnace the temperature is maintained by combustion of gas in the furnace chamber, and the atmosphere is oxidising to a greater or lesser extent. Any control over the reducing conditions in an open-hearth furnace must, therefore, come from reducing agents in the metal, and very limited control, if any, can be had over the action of agents such as silicon or dissolved carbon. Since oxide of iron cannot be kept from forming in the slag under influence of the furnace atmosphere, it is apparent that the silicon or carbon in the metal are the agents which must be relied upon to prevent such oxidation.

To hold the strongly-acid oxide of phosphorus in the slag requires a fluxing agent, such as lime, having a strong affinity for phosphorus, and which is strongly basic in chemical nature. Calcium phosphate is not at all difficult to reduce, however, at an elevated temperature and with strong reducing agents, and either silicon or carbon is capable of reducing it. This statement holds true even though the carbon or silicon be dissolved in iron, although the intensity of the reducing action is then less, possibly owing to the *pulling action* of the iron itself on these reducing elements. The temperature may, of course, greatly influence the action on the slag of these reducing agents contained in the metal, and may so change their affinity for oxygen as to prevent reduction of certain oxides in the charge, as is the case with carbon and phosphorus.

In an open-hearth furnace calcium phosphate will be reduced from the slag back into the metal when the conditions of equilibrium between the oxides of iron in the slag and the reducing agents in the metal are such as to reduce the amount of iron oxide below a certain limit. Silicon is such a strong reducing agent that practically always, except in certain cases to be noted later, it must be oxidised out of the metal before the phosphorus is attacked. If present in the bath it reacts with any oxide of phosphorus present and reduces it. The presence of large amounts of silica in the slag or lining of the vessel is ordinarily detrimental to removal of phosphorus.

The influence of carbon, the other important reducing agent in the metal, is largely dependent on the temperature, its affinity for oxygen being less than that of phosphorus at low temperatures, and greater at temperatures above about 1,540° C. Thus, at low temperatures, carbon dissolved in the iron is not a strong enough reducing agent to reduce calcium phosphate held in a slag high in oxide of iron, but at higher temperatures it is. Thus, either by means of silicon or by means of carbon contained in the metal, or, of course, by solid carbon, the oxide of iron in the slag may be readily reduced, and when such reduction proceeds far enough, calcium phosphate is also reduced and the phosphorus goes back into the metal.

The fact that at low temperatures phosphorus is more easy to oxidise out of the metal than carbon, is the basis of several modifications of the open-hearth process, such as the Krupp washing process, the Bertrand-Thiel process, &c. The slight differences in these processes, such as the heating up of ore, lime, and pig iron together, or the preliminary heating of the ore and lime and subsequent use of molten pig iron, do not change to any great extent the final result as to the method of removing phosphorus. The manner of carrying out this oxidation of phosphorus determines the degree of activity and frothiness of the slag, but essentially the reaction is the formation of calcium phosphate in the presence of considerable oxide of iron.

In the operation of the basic Bessemer process, the chemical reactions involved in the separation of phosphorus

are in reality practically the same as those in the open-hearth process. In the Bessemer process, temperature is maintained by combustion as in the open hearth, the combustible materials being the silicon, phosphorus, iron, carbon, &c., of the charge, and also these are burned with an excess of oxygen to produce the necessary heat. Oxidation of the phosphorus results from oxygen of air primarily, but oxide of iron formed from the air acts as a carrier of oxygen, just as in the open-hearth process the slag serves as a carrier of oxygen from the furnace gases.

A large proportion of the heat evolved in the basic Bessemer process results from the oxidation of phosphorus, but it has been found that a certain proportion of silicon is necessary in the pig iron to produce the requisite final temperature. Silicon is oxidised first, together with iron, and thereby the temperature of the bath is raised above that known as the critical temperature between carbon and phosphorus, and above this critical temperature the phosphorus is not removed appreciably until after both the silicon and the carbon are largely oxidised out. In certain cases with low silicon, oxidation of phosphorus takes place from the early part of the blow simultaneously with that of carbon. This is what would be expected if the temperature were held at about the critical point, since at this temperature the oxidation of carbon and the formation of calcium phosphate take place with equal readiness.

An interesting example of the effect of metallic reducing agents in connection with the basic Bessemer process is the rephosphorisation of the metal on the addition of spiegel. The spiegel enters the metal at a high temperature and through a slag containing considerable quantities of calcium phosphate. At an elevated temperature both silicon and manganese are easier to oxidise than phosphorus, and these two elements tend to reduce the phosphorus from the slag back into the metal. From recent experiments it has been found that at a low temperature phosphorus, on the contrary, is more easily oxidisable than manganese in the presence of lime, and can be separated as calcium phosphate without the oxidation of manganese.

On comparison of the conditions in the Bessemer and open-hearth processes, it is seen that the controlling factors in the separation of phosphorus are almost identical. Lime is, of course, necessary to hold the phosphorus in the slag. Combustion is the source of heat, and iron oxide is always present and usually in large amounts; silicon oxidises before phosphorus, and the oxidation of carbon before or after phosphorus is determined by the temperature. Lack of complete control over the reactions resulting from producing the requisite temperature by combustion in the furnace chamber, and necessitating loss of iron as oxide in the phosphate slag, is the very feature which electric heating can correct.

The electric furnace has been found well adapted to removing phosphorus by oxidation in the old way, but not commercially, and on careful consideration it is difficult to see how it could do so commercially in competition with the open hearth. The process of removal of phosphorus in the Héroult furnace, for example, as practised by the United States Steel Corporation, has been to charge blown steel into the furnace and melt on top of it a slag of lime and iron oxide. The reactions are identical with those in a basic open hearth. And in spite of the fact that the temperature can be maintained high, the removal of phosphorus in a large furnace takes anywhere from 20 minutes to 1½ hours, according to the amount of phosphorus removed. After the phosphorus is separated in a slag high in oxide of iron, that slag has to be removed in order that the bad effects of the oxides contained therein on the steel may be remedied. It is certainly difficult to see wherein lies the advantage of using costly electrical energy, electrodes, &c., to do the same thing that is done with cheaper fuel heating in a basic open hearth. And this is gradually becoming realised. After removing this first slag, it is replaced by a reducing slag to remove the oxygen from the metal. Here metallurgists have gone to the other extreme; they have aimed at and obtained the strongest reducing conditions possible by use of solid carbon and high temperatures. They have used as a measure of the intensity of such reducing conditions the formation of carbide in the slag, and these conditions are such as will readily reduce phosphorus compounds in the slag.

One method of avoiding two slags was proposed and tried out. It consisted in the use of a solid reducing agent, such as fine coke, added to the oxidising slag after the phosphorus had been taken up by that slag. The object of this was to reduce the iron-oxide of the slag and leave the phosphorus as calcium phosphide. The results of the tests on this process indicated that the use of a solid reducing agent at the elevated temperatures necessary in a steel furnace not only reduces the iron, but also the phosphorus, and the latter goes back into the metal. No other result could have been expected. The explanation of the above reaction is simply that solid carbon has a stronger affinity for oxygen than has phosphorus at the temperature of molten steel in an electric furnace, even though the phosphorus be combined with lime as calcium phosphate. In other words, the reducing conditions acting on the slag are so strongly reducing that phosphorus goes back into the metal.

High phosphorus iron ore has been partially reduced in the presence of lime without practically any of the phosphorus entering the metal, the phosphorus being retained in a slag very high in oxide of iron. Such reduction of iron and separation from phosphorus has been carried out in an electric furnace by using insufficient carbon to completely reduce the ore, since solid carbon, if present, will of course reduce the calcium and iron phosphates at the elevated temperature maintained. The action here of solid carbon is similar to that in a blastfurnace, where the presence of an excess of solid carbon causes reduction of oxide of phosphorus and phosphorus is found in the metal. In an electric ore reduction furnace, even with a basic lining, excess of coke will produce the same result, and the presence of lime does not overcome this effect. On the other hand, in an electric reduction furnace, when the carbon-reducing agent is limited, the phosphorus does exactly what it does in an open-hearth. These facts show why it is not possible to reduce iron from the first slag in the Héroult steel refining furnace by use of coke without reducing phosphorus back into the metal.

It is a fact that at an elevated temperature oxide of iron is more easily reduced than calcium phosphate, and it is evident that if the proper intensity of reducing conditions be maintained at the elevated temperature, oxide of iron may be completely reduced without reduction of calcium phosphate. Such conditions are obtainable by use of a gaseous reducing agent, such as ordinary producer gas, meanwhile maintaining the temperature electrically.

The various reactions of phosphorus associated with iron may be summarised as follows:—

At temperatures under 1,450° C., phosphorus in pig iron has greater affinity for oxygen than has the carbon in the pig iron, but less affinity for oxygen than solid carbon in the presence of pig iron.

At temperatures above 1,450° C., the affinity of the carbon dissolved in iron for oxygen becomes greater than the affinity of phosphorus in the iron, and the dissolved carbon can reduce calcium phosphate in the slag; of course, solid carbon can do this also.

Phosphorus oxidises in presence of lime and iron oxide to calcium phosphate, in absence of silicon or solid carbon.

Silicon reduces calcium phosphate nearly always, but there may be a range of temperature under 1,450° where phosphorus oxidises to calcium phosphate more easily than silicon to calcium silicate.

Solid carbon will reduce calcium phosphate contained in a slag or bath of iron and phosphorus will go into the metal.

Calcium phosphate can form without oxidation of iron in presence of carbon dissolved in pig iron at low temperature.

Calcium phosphate can form without oxidation of iron in the absence of carbon and silicon at high temperatures, in other words, above 1,450° C.

Oxide of iron can be reduced without reduction of calcium phosphate contained in the same slag.

Solid carbon is a stronger reducing agent than carbon dissolved in the iron, probably because of the affinity of the metal for carbon.

It is apparent that in all of the present processes the complete control of at least one important factor is either lacking or has not been utilised. In the open-hearth process it is the

control of the reducing conditions that is limited, and likewise in the Bessemer process; but in this latter process the control is further limited by the necessity of raising the temperature by oxidation of elements in the charge itself. In the electric furnace, however, where heat can be produced independently of combustion or chemical reaction, this important factor—namely, intensity of reducing conditions—can be controlled at will and with ease. Up to the present time this fact appears not to have been appreciated by metallurgists, judging by present methods. It is in the complete control of the reducing conditions that important possibilities of electric heating lie, and as this fact becomes more generally recognised and used it is probable that some method will be devised for measuring the intensity of reducing conditions or equilibrium conditions. Since the intensity of reducing conditions is the reverse of the intensity of the oxidising conditions, the term oxygen pressure may find use as a measure of them.

Among the reactions made possible by control of the reducing conditions and temperature simultaneously, is the reduction of oxide of iron from a slag containing calcium phosphate without reduction of the phosphorus contained therein. Naturally, the origin of the phosphorus containing slag or charge is immaterial; it may be raw ore containing phosphorus, or it may be a slag in which some of the original oxide of iron served to provide the oxygen for combination with phosphorus, the oxide of phosphorus subsequently combining with lime to form phosphate. Or the reducing conditions may be so controlling as merely to prevent oxidation of iron, which, at the same time, causes phosphorus to oxidise and combine with lime.

In the writer's experiments along this line it has been found that at temperatures below about 1,400° the phosphorus was easier to oxidise than carbon from pig iron. And it was found that the phosphorus could be oxidised in the presence of lime without any resultant oxidation of iron and with practically no oxidation of carbon; that phosphorus could be oxidised in the presence of lime without oxidation of manganese; and a very interesting further observation was made, namely, that at certain temperatures between the melting point of pig iron and about 1,350° C., phosphorus oxidised in certain cases in the presence of lime without any appreciable oxidation of silicon. This would indicate a reversal of oxygen affinity of these elements—phosphorus and silicon in pig iron in presence of lime.

A fusible slag results from proper proportions of acid and basic radicals. It has been found that the silica content in the slag may be as high as 30 per cent. without apparently hindering the removal of phosphorus. Phosphorus was separated in slags containing this amount of silica and yet practically no iron oxide was present in that slag. This points to the possibility of a low-melting point slag for holding phosphorus.

The reduction of oxide of iron from a charge or slag containing phosphorus as calcium phosphate, without reduction of the latter, requires essentially the same control of the conditions as does the selective oxidation of phosphorus in presence of lime, forming calcium phosphate without oxidation of iron. Electric heating is the only practical way of accomplishing such control.

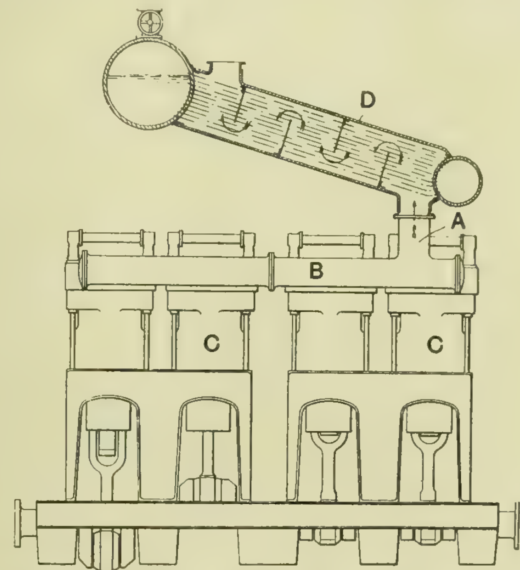
It is not to be doubted that metallurgists will very soon appreciate the distinction between various degrees of oxidation and reduction, where they have not already done so, since in so many cases undesired elements can be separated from metals by oxidation of the impurity and reduction of the metal. When this becomes generally appreciated it is prophesied that electric heating will come into use to an extent that is now hardly thought possible.

Automobile Engineers' Visit to the United States.— The invitation of the American Society of Automobile Engineers to the Institution of Automobile Engineers to visit the United States in the spring of next year has now been extended to members of the Society of Motor Manufacturers and Traders, Ltd., and has been accepted by them. A joint committee of the two English bodies is at work on the preparation of the programme. A number of automobile factories will be visited, together with works producing steel springs, tyres, carriage work, and other details of the automobile.

COMBINED TURBINE AND OIL ENGINE PLANT FOR SHIP PROPULSION.

In the subject of ship propulsion, prominence is given to the obtaining of as much power as possible without undue weight, with the result that various combinations of driving means have been proposed. In one combination, turbines and internal-combustion engines of the Diesel type are used with means for enabling the same to be used alternately for high and low speeds respectively. In this combination the turbine rotors always rotate with the propeller shafting irrespective of whether the drive be effected by the internal-combustion engine or turbine plant, the stators of the turbine rotors in the former case remaining connected up to the condenser. Now in practice it is found that the power actually absorbed by the turbine plant without contributing directly to propulsion, even at low speeds, is appreciable.

With a view to decreasing this loss, Messrs. John I. Thornycroft & Co., Ltd., Woolston Works, Woolston, Hants, propose in a recent patent to utilise the exhaust products of combustion from the internal-combustion engine plant in a boiler adapted for dealing with gases which are comparatively



COMBINED TURBINE AND OIL ENGINE PLANT FOR SHIP PROPULSION.

low in temperature and to direct the steam thus generated into the turbine plant, where it will perform the useful service, even if at low pressure, of enabling a vacuum to be maintained in the turbines by the ordinary air pumps, which is not possible if no steam be delivered into the turbines owing to the air leakage that usually takes place rendering it impossible to maintain a satisfactory vacuum in the turbines. Any steam produced in excess of that necessary for the purpose just mentioned can be used to drive the air pumps and any other auxiliaries direct. Any further steam that may be available can be delivered into the turbine, where it will do work and assist in driving the rotor therein and propelling the ship. In this way, heat units formerly wasted can, it is claimed, advantageously be used to maintain a vacuum in the turbines, and also it may be to assist propulsion, and thus compensate indirectly as well as directly for the power heretofore absorbed in the turbines.

The arrangement is illustrated in the accompanying drawing, which shows, in elevation, a branch pipe A leading from near one end of the exhaust receiver B of the Diesel engine C connected to a steam generator D of any suitable type adapted to utilise the heat of the hot exhaust products of combustion from the engine for generating steam, which is admitted to the turbines, for use therein for the purpose mentioned; any steam in excess may be used in the engine driving the air pumps or other auxiliaries.

Cadmium.—Practically all cadmium produced is obtained as a by-product in zinc smelting, as it is found associated with zinc ores.

THE ECONOMIC USE OF LUBRICATING OILS.*

BY DAVID A. COREY.

THE harder and more exacting the service required, the more the attention which should be given to the subject of lubrication. This applies not only to the selection of oils suitable for the various requirements, but quite as much to a proper method of storing, dispensing, and otherwise caring for and conserving the materials purchased. Oil costs money; it is an important factor in the successful operation of machinery. The lack of oil or failure to properly care for the oil in use is a serious matter and is, perhaps, more than any other one thing the cause of failure to secure maximum efficiency in machine operation; and that loss costs more money. This applies with equal force to the power house, to the machine shop, to transmission machinery, and to the producing machinery.

The selection of oils for the many requirements of a manufacturing plant is a matter which is worthy of many expert and practical tests to determine what lubricants are best for high, medium, and low speeds, for light and heavy journal bearings, &c. It is generally conceded that such tests are the only true means of definitely determining what oils render the best service under different conditions. Reliable oil manufacturers are prepared to submit the results of such tests and, for fixed and definite service, to guarantee results.

To make the saving and low costs of oils effective to the highest degree, it is necessary, after the selection of oils has been made, to provide suitable means for properly storing and issuing them. The common plan of keeping oil in barrels is especially wasteful. It has been well said that barrels are for transportation, not for storage purposes. The loss by seepage, evaporation, absorption, non-drainage of barrels, and from faucets would be appalling if realised by the men who pay the bills. Practical tests in manufacturing plants by engineers who are constantly studying this subject show actual losses in lubricating oils of from 5 to 25 per cent., or 2 to 12 gallons per barrel of an average capacity of 50 gallons.

An important phase in oil and manufacturing economy, when the character of machinery renders possible the necessary equipment, is the re-use of oil. To re-use oil it must necessarily have all impurities that will cause damage removed. In many plants the oil used is caught and again used on rough work, where the impurities will do no appreciable damage. It may seem that in such cases the loss has been well guarded against, and that any further saving would be too small to justify an investment or the spending of much time in its consideration; but lubrication economy means vastly more than the first cost, for the lubricant supplied may be entirely used up in service with virtually no waste or "drips," but this is not economical lubrication. Practice has demonstrated that there is always another item of expense besides the oil cost, and that is the cost of repairs or renewals due to injury arising from too scant lubrication, and this practice has coined the expression "sufficient lubrication." This term is wholly inadequate and misleading, for as commonly used it means only enough lubrication to prevent injury to the journal. It in no way measures the economy of lubrication, but rather defines the limit of loss that is endurable without destroying the journal.

In modern practice the so-called "sufficient" lubrication is no longer considered adequate; flooded journals are demanded and the highest economy requires the re-use of oil. No half-way provision is tenable, and if oil is to be re-used, there is no object whatever in restricting its use. Oil losses are due to destructive distillation at the journal. A greater quantity of oil produces less friction, therefore less heat and less distillation loss. The friction losses are governed to a very large extent by the quantity fed.

To secure satisfactory service in re-using oil it must be thoroughly cleansed. Old oil is not different from new if the impurities be removed. Petroleum oils never wear out, any more than water, but the lighter properties can be lost by distillation, which may occur at the temperature of an improperly lubricated journal, and to avoid this, it is necessary to keep journal temperatures low, or in other words, to reduce friction by the use of large quantities of oil. The re-use of oil is now common in nearly every factory, by means of ring-oiled bearings. Nobody looks upon this as much of a hazard, but if the dirty oil were taken out of the ring-oiled bearing and put into an oil cup on some other machine it would be looked upon as unwise and dangerous. As a matter of fact it would be both.

In the case of ring-oiled bearings, as the impurities increase in quantity they retard the flow of oil; and if the oil is not drawn off and the bearings cleansed out it will cause serious cutting of the journals. This cutting may not be very plainly manifested, in fact the operator is more than likely to think that he has no trouble with his ring-oiled bearings. Furthermore, he may look upon the excessive wear as natural wear, while in fact it is due entirely to dirty oil, and consequent inability to keep the journal faces the necessary distance away from each other to permit the impurities to freely pass between. The highest lubricating efficiency, therefore, demands clean oil as well as the large quantity.

The losses due to faulty lubrication are far greater than are generally recognised. In the power plant the friction (and consequent fuel) loss is a conspicuous item. To reduce this loss much oil must be used, and the amount of oil used will determine the saving possible in fuel. The saving possible in the engine room is frequently of such magnitude that an investment equal to the yearly coal cost would be justified, but as a matter of fact, only about one-tenth this amount is necessary to get the best possible results.

Ordinarily, 200 times as much oil can be fed upon the journals of an engine as would be the minimum amount possible. The chart (Fig. 1) shows the different savings when

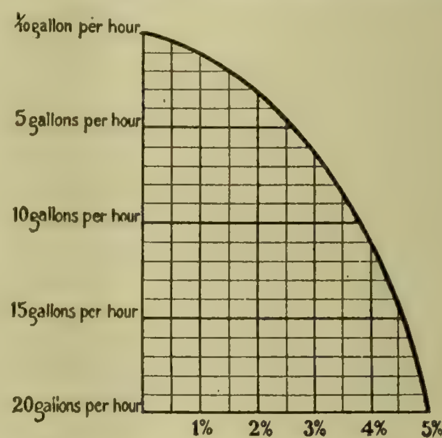


FIG. 1.

feeding different quantities, and when the total maximum saving is 5 per cent. For instance, if five gallons per hour be circulated, the saving would be 2½ per cent.; if 20 gallons an hour be circulated it would effect a saving of 5 per cent., an amount which is invariably possible. The amount of oil shown in the chart would be that required for a 750 h.p. engine. The use of stream-fed, well-filtered oil is always possible and profitable in any engine room, paying ordinarily from 50 to 100 per cent. yearly return on the investment.

William L. Morris, in an article in the "Engineering Magazine," April, 1912, entitled, "Oiling Systems that Pay 100 per cent. Dividends," says: "An oiling system that will reduce friction 5 per cent., will effect savings in one year's time sufficient to pay the entire cost of installation, and if run 24 hours a day it will effect even more. To secure the ultimate savings possible, it is necessary that the system be exceedingly large in all its provisions, and that it can be easily kept clean. It should be possible to clean all parts of the system while it is in service; men will not work overtime if they can avoid it, the result being that cleaning would be neglected. A 100 per cent. system cannot be obtained with less than 2 sq. ft. of filtering surface for each gallon of oil filtered per hour, and the capacity should be not less than 200 times what would be possible with a minimum hand feed. The percentage value of a system closely approximates the amount of surface furnished and, in common with all machinery, the price does not increase as much as indicated by the quantity. If an engine room be supplied with a small system having 10 sq. ft. of surface when it should have 100 sq. ft. there will be a constant yearly loss of nine-tenths the value of the larger 100 per cent. system."

* Abstract of paper read before the National Association of Cotton Manufacturers, New London, Conn.

Oiling systems and ring-oiled bearings have come into use during the life of the present operators and have met with opposition from the start. The first obstacle was the general prejudice against re-using oil; and following this was the reluctance of manufacturers to make up new patterns suitable for the re-use of oil. Bearings for line shafts were first arranged for grease, then for wick or capillary oiling, and now the use of ring, chain, or collar oiling is quite general throughout the factory. The general tendency in the matter of oiling shafting is correct, as all general tendencies are bound to be. Light oils in abundance are the friction savers and savers of machinery, and to make this system a perfect success it is necessary to eliminate as far as possible the re-use of dirty oil. The continuous circulation of a very large quantity of clean light oil is the last word in lubrication; it assures the greatest benefits possible and at a cost not greater, and in most cases much less, than the poorest lubrication that will barely keep the journals from destruction. These facts being fully appreciated, it is then wholly a matter of application.

It may occur to the power user that since his machinery has not been equipped for stream-fed lubrication, it would not pay in his case to arrange for such. It is doubtful if there are any such hopeless cases. If the best practice is not obtainable, at least a far more efficient system may be employed than the existing scant or drop-feed oiling, or the re-use of dirty oil. The physical conditions of the plant must determine just how perfect a system can be employed. The bearing shown in Fig. 2 is one especially suited for stream feed and drips drained away, this permitting the highest possible grade of lubrication. The oil runs off the bearing and cannot be returned to it until it has passed through a filter, and such impurities as would injure the journal removed. The collars on the end of the journal prevent the oil creeping along the shaft. This form is as safe against shut down as any system that can be devised.

Another method of increasing the efficiency of ring, collar, or chain-oiled bearings is to occasionally wash out the bearings and supply them with clean oil. This is more troublesome and not so efficient as the piped system shown in Fig. 2, but it is probably the most efficient arrangement used at present for shafting, motors and the like. The great objection to this method is that little attention is given to a journal after it has been filled with oil. Possibly once a month a little more oil is poured into the oil receptacle, and nobody ever thinks of cleaning it out. This is the use of dirty oil in its worst form. There is enough oil in the journal to keep it from melting out the babbitt, and that is about all that can be said.

By observation and comparison of the power required to drive a line of shafting and the idle running machines, first with clean and then with dirty oil, and knowing the length of time this loss was endured, it can be readily determined whether it pays to change oil every month, or oftener. If the saving in power alone is equal to the labour cost it would be justified, as all other savings would be clear gain. But for heavily loaded, troublesome bearings, flooded lubrication should be provided. If they cannot be connected to a central oiling system, then provide an individual system with possibly a rotary pump run by the machine. The re-use of a large quantity of oil is imperative wherever friction is at all noticeable, and it is safe to assume that some satisfactory arrangement can be provided. Hot or troublesome bearings are positive indications of careless or indifferent regard to operation economy. The application of grease, graphite and the like may aid, but it cannot eliminate the lubrication loss. Wherever grease is essential for operation look closely for something wrong. Flooded journals will stand virtually any service to be met in ordinary factory service, and to provide flooded journals we must use the same oil over and over; there is no alternative.

But little has been said in regard to the machines in the factory. If the bearings be small, requiring but little oil, and no provision has been made for flooded lubrication, it is safe generally to assume that the economies to be derived will not justify the expense and complications which would be met, but in securing new equipment an effort should be made to have stream-fed or ring-oiled bearings. In many cases the hand oiler must continue, and it must, in fact, be conceded that in the textile mill the conditions are such as to make this method necessary, but many special devices for safely storing and handling have been designed as the basis for conserving the oils, to minimise the cost and assure ease and accuracy in handling, to preserve the quality, to keep the oil free from dust and lint and to reduce the fire hazard to the minimum.

The common method of distribution in mills is by means of tanks of 10 to 60 gallons capacity in the different departments, the sizes depending upon the judgment of the management. Some prefer few large tanks, while others prefer small tanks placed at more frequent intervals. The latter plan is satisfactory as the small tanks can be removed from the mill for filling at the storage house outside, and in the mill are more conveniently located for the operatives.

When small tanks are used, several of them (four or six) can be transported on a truck to the storage-room and returned in the same manner after filling. A tank of this kind should preferably be equipped with a non-overflow discharge, so that the oil cups can be quickly filled without spillage and without the usual accompaniment of waste, which becomes saturated with oil, is thrown away, and becomes a fire menace. Another method of distributing to tanks in the mill is by means of portable tanks, which are filled at the storage room, wheeled into the mill, and the oil discharged into the permanent tanks by means of pumps.

These methods are decided improvements over the present common one of taking barrels on elevators to the different floors, rolling them through the mill to the stationary tanks, and using transfer pumps or similar methods for transferring the oils from barrels to tanks. Leaky, and sometimes broken, barrels leave traces behind, and this custom is dirty and dangerous.

A third method, and one which is being largely adopted for certain factory uses and does away with transportation about the plant, is by means of long-distance pumps operated by hand

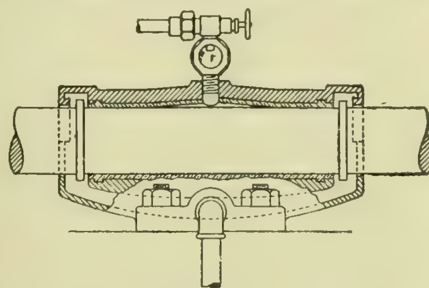


Fig. 2.—Design for Stream-fed Bearing.

or power, located at convenient points about the factory and drawing the oils from one central storage point. The advantages of this system are manifest, especially where large quantities of oils are used in manufacturing operations, and measurements of the quantity delivered is desired. In utilising any of the plans suggested, to get the full value of the system the amounts issued to each department should be charged against that department, and to this the measuring features of the supply pumps are of great assistance.

Still another method of delivering and measuring oils and other liquids is by means of an electrical remote-control system of pumps and measuring devices, used in manufacturing operations where considerable quantities are required in mixing, compounding, &c. The measures are automatic in delivering any desired or predetermined quantity

The whole subject of oil handling and lubrication efficiency is now recognised as one of great importance, as is shown by the consideration and study which has brought about the development of special apparatus and the investment of capital in its manufacture to meet the needs and demands. It is a subject large enough to warrant the attention of every manufacturer and the advice of experts, for it is directly and indirectly a considerable factor in the cost of operation and production, and upon efficiency depends dividends.

The Elgar Scholarship.—The Post-graduate scholarship in Naval Architecture, which is known as the Elgar Scholarship, and which is offered for competition by the Council of the Institution of Naval Architects, has for next year been raised in annual value from £50 to £100. It is open to students of the Institution of British nationality, and is, subject to certain conditions, tenable for three years.

THE SELECTION OF LOCOMOTIVES.*

By O. S. BEYER, Jun.

THE problem of locomotive design is comparatively simple when it is clearly known what is desired. The possibility of effecting operating results by the introduction of improved locomotives alone, or by their use in connection with such changes as grade revision, is not as fully appreciated as it ought to be. To make an intelligent selection of motive power for a railroad, it is necessary to study the effect which various types and sizes of locomotives will have on operating expenses and fixed charges. Statistics published by the Interstate Commerce Commission covering the entire railroad field of the United States show that 55 per cent. of the operating expenses are affected more or less directly by the motive power. The wide range of motive power now available will have to be considered in future double track and relocation work, grade reduction, elimination of rise and fall, and curvature and distance, in order to effect the greatest economy possible for the capital expended. It should no longer be necessary when relocating a division to increase its capacity and reduce operating expenses, to go to extremely heavy capital expenditures to reduce grades to the minimum of 0·2 or 0·3 per cent., as it is usually much cheaper to provide locomotives of greater power.

The main steps in the careful selection of motive power may be divided into the consideration and study of: (*a*) The service; (*b*) The nature of the business; (*c*) The topography of the road, train speed and train resistances; (*d*) The types and sizes of locomotives available; (*e*) Improvements to the permanent plant; (*f*) Effect of various types and sizes of locomotives on operating expenses; and (*g*) final selection of most economical type and size of locomotive.

The Service.—Motive power is used in three general classes of service, namely, passenger, freight, and switching. Passenger service may be further subdivided into the following classes: High speed or through service, and suburban or local service. Freight service may be subdivided into slow or drag service, fast freight service, and pusher service. Consideration of the service will determine whether the engines are to be built suitable for just one class or for a combination of classes, such, for instance, as switch and helper service, slow and fast freight service, freight and helper service, or passenger and freight service. This goes hand in hand with the consideration of some of the other features, notably the amount of and the different kinds of business, the size and types of engines available, and the effect of the engines under consideration on operating expenses.

Nature of the Business.—The special nature of the business, while intimately related to the general service for which the engines are intended, deserves some particular consideration. Through passenger service, for instance, may vary between long distance high-speed hauls, and slow speed frequent stop hauls. Freight service, especially, may vary between hauling almost exclusively trains of low class bulk commodities, such as coal and iron ore, which generally move in well built high capacity steel cars at slow speeds, and hauling trains, of a decidedly mixed nature, loads and empties, box, furniture, flat, automobile, gondola and stock cars, which are not of high carrying capacity and are seldom fully loaded, resulting in trains of great length when any large amounts of tonnage are hauled.

Due to the generally inferior construction of cars which compose a mixed train, the weakness of the draught rigging of the older cars, the limitations of the older types of air-brake equipment, and the tendency to long trains when heavy tonnage is handled on railroads where this class of business is general, the motive power problem assumes an aspect entirely different from that on roads where the business is of the nature first mentioned. In switching service the demand may vary between straight yard work and hump work, and in pusher service it may vary between passenger pusher and freight pusher work.

Topography, Train Speed, and Train Resistance.—The consideration of the topography, train speed, and train resistance of the territory in which the new engines are to operate will at this time only take recognition of hauling capacities and train lengths. The extensive research work recently conducted by many eminent investigators, railroads, and locomotive builders, furnishes reliable information and data from which to determine very exactly what the hauling capacities of different types and sizes of locomotives are and the speeds and resistances of the trains which can be hauled by them. The hauling capacity at different speeds depends on the sustained tractive effort, which in turn depends upon the boiler capacity and the engine efficiency. Locomotives intended for high-speed service should have high sustained tractive efforts. Locomotives for heavy drag and switching service should have high tractive efforts at slow speeds, and may sacrifice high sustained tractive efforts at high speeds in order to attain this end. When selecting locomotives to meet certain conditions in regard to train weights, train speeds, and opposing grades, it is necessary to analyse the situation from this standpoint.

Grades, speeds, and train resistances must be very thoroughly considered when new passenger engines are to be purchased. Passenger engines are intended for high-speed work. Modern operating conditions frequently present cases of heavy trains composed of all steel cars. The weight of passenger cars, due to the desirability of greater passenger carrying capacity and heavier construction, is rapidly increasing. Hence, the most essential quality to be provided in a passenger engine is the ability to maintain large sustained tractive efforts at high speeds, as well as high starting efforts at low speeds. This ability of a passenger engine is secured by providing ample boiler capacity and good steam engine efficiency. The ability of a passenger engine to accelerate rapidly is another quality which must be considered, particularly if the engine is to be engaged in service in which stops are frequent. The power required for high rates of acceleration, especially on grades, with heavy passenger trains is enormous. Since the locomotive power available is limited principally by the steaming capacity of the boiler, the larger this steaming capacity the sooner will the engine be enabled to reach its maximum speed.

Freight and pusher engines are engaged in a service which requires at the critical time very high tractive efforts at slow speeds. This depends to a large extent upon the weight placed on the drivers and the total weight of such engines must thus be so distributed that a relatively large weight falls on the drivers. With the cylinder and driver dimensions and the boiler pressure so arranged that the maximum tractive effort at the rim of the drivers equals 22 to 25 per cent. of the weight on the drivers, a satisfactory combination for an engine for ordinary freight service is secured.

Modern conditions demand an increase in fast freight service and relatively large sustained tractive efforts at high speeds over heavy grades are becoming more necessary than ever. Locomotives for fast freight service only, may afford to sacrifice some initial tractive effort for the sake of having recourse to a proportionately larger heating surface when great quantities of steam are necessary at high speeds. Pusher engines and road engines on the other hand, intended exclusively for slow service may be permitted to have a large tractive effort capacity at slow speeds with a sacrifice in high sustained tractive efforts at high speeds.

The large majority of freight engines purchased are intended for a class of service which is a combination of fast freight and drag or slow freight service. Under these circumstances it is usually desirable to get as large a steaming capacity as possible consistent with a high tractive effort at low speeds. Incidentally, engines with good steaming capacities when operated with heavy tonnage trains are proportionately more economical in fuel and water consumption, as well as capable of maintaining a higher average speed over the entire division.

Consideration of the topography of the railroad and the hauling capacity of freight locomotives presents the problem of permissible train lengths. If the territory over which the locomotives are to operate is, to a large extent, a succession of many sags and pitches and contains several momentum grades, the continual running in and out of the slack between the cars is a serious matter and tends to limit the length of the train and the amount of tonnage per train which can be hauled. The nature of the business, whether it is ore, coal, or pig iron moving in high capacity modern steel cars, or general merchandise moving in box cars, refrigerators, small capacity gondolas, or other similar

*Paper read at the annual meeting of the American Society of Mechanical Engineers, December 5th, 1912.

cars has a further bearing on this feature. The lower the average total car weighs of trains the longer the trains when large amounts of tonnage per train are hauled.

The introduction of high capacity friction draught gears, steel underframes, and improved air brakes is tending steadily to minimise the difficulty of operating very long trains. The perfection of the variable load brake may help further in this direction. Cases are on record where trains of 90 and even more loaded cars, each car weighing 70 tons, have been hauled with success. Trains of 125 empty cars are not unusual in daily operation. Most of these extremely long trains are running over territories whose grades are low, or which have no broken profile. Furthermore the nature of the lading hauled in these exceedingly long heavy trains, is such that, should any heavy shocks occur, the lading cannot be damaged. Cars filled with automobiles, furniture, or general merhandise, or flat cars loaded with agricultural machinery, are different and must be handled with greater care in shorter trains. Every district for which motive power is intended presents certain little peculiarities when advisable train lengths are considered. Experience in the operation of trains hauled by the older types of locomotives must assist in determining the final answer to this question. As a rule there are a great many circumstances, such as the capacity of the side tracks and other conditions of the permanent way, which are apt to limit the length of trains before the profile conditions establish limitations.

Sizes and Types of Locomotives.—The principal types of locomotives available for passenger service are the Atlantic (4—4—2) type and the Pacific (4—6—2) type. The American (4—4—0) type, the Ten-wheel (4—6—0) type, and the Prairie (2—6—2) type have been employed to some extent, but except in unusual cases are not of special advantage. The latest development in passenger engines for severe mountain service is the Mountain (4—8—2) type. In some special cases, such as exceedingly heavy mountain service, the Mallet engine has been used.

The Atlantic (4—4—2) type locomotive is usually best adapted to a service in which the trains weigh about 300 to 350 tons behind the tender and the grades encountered are relatively light. Owing to its wheel arrangement it permits of a boiler of ample capacity in proportion to the cylinders. It has a short rigid wheel base and a short total wheel base. To get very high initial tractive efforts with locomotives of this type means exceptionally high axle loads, which are undesirable. Hence, when high initial and sustained tractive efforts are required for heavy trains weighing over 350 tons behind the tender and operating over heavy grades, the Pacific (4—6—2) type is usually found to be better. The wheel arrangement of this type permits a still larger boiler, greater total weight on drivers with lower average axle loads, and large cylinders. In general, the full utilisation of these features results in both higher initial and higher sustained tractive efforts, combined with better accelerative qualities.

For exceptionally heavy mountain service the Mountain type permits of still larger boiler capacities and greater total weights on drivers, and hence still higher tractive efforts. Several engines of this kind are in service hauling trains weighing 600 to 650 tons over grades of 70ft. per mile at 25 to 26 miles per hour. Mallet engines have been introduced to a limited extent in passenger service.

The Atlantic and Pacific type engines, under modern operating conditions, are, for high-speed and high-capacity passenger service, the most desirable types. Under certain special circumstances, long continuous opposing grades may justify compounding in connection with these engines. The introduction of the high temperature superheater and the sectional brick arch have helped materially to increase the capacity, fuel economy and efficiency of passenger engines. The limitations of Atlantic and Pacific type passenger engines are principally controlled by the permissible wheel loads. When 60,000lbs. to 63,000lbs. per pair of drivers is once reached, it is questionable, from many points of view, whether it is wise to go still higher. Hence, when greater tractive efforts are necessary than can be secured from an engine with 180,000lbs. to 190,000lbs. on drivers it becomes a question of either reducing schedules, double heading, or introducing locomotives with an additional pair of drivers.

Recent developments have made available an exceptional field from which to select locomotives for freight service. It seems limited not so much by the extent to which it is possible to build freight engines as it is by the physical restrictions of the permanent way, the nature of the freight business hauled, length of trains, and topography of the road. These limitations are, of course, mostly very serious and, as far as track gauge is concerned, insurmountable, except perhaps in some special cases. Many Moguls (2—6—0), Ten-wheel (4—6—0) and Prairie (2—6—2) type locomotives are in freight service to-day. Their capacities, especially the Mogul and Ten-wheel types, are hardly adequate for modern service conditions. The Prairie type, due to the possibility of equipping it with a liberal boiler and liberal grate area, has a few advantages over the others.

The type of locomotive which has been the standard on many of the American railroads in the past ten years is the Consolidation, or 2—8—0 type. It has been called upon to perform in services ranging from emergency passenger to slow heavy pusher and switching service. Engines of this type are being built for heavy and exacting freight service and their possibilities have not been exhausted. They utilise nearly the total weight of the engine for adhesive purposes. A leading truck of two wheels only is provided permitting of a slightly extended boiler and taking from the drivers only weight enough to secure good guiding qualities. The steaming capacity, firebox size and grate area are necessarily limited, since the entire boiler and firebox must be carried over the drivers. The handicap imposed by the boiler limitations has not, until recently, been very serious. Engines of the Consolidation type, having a maximum tractive power of 60,900lbs. are in service to-day. The diameter of their drivers is small, 54in., and their total heating surface compared with the equivalent heating surface of a Mikado engine having the same tractive effort, is but 70 per cent. as great. The piston speeds of these large Consolidation engines, compared with the Mikado engine, are considerably higher.

The perfection of the high temperature superheater, the brick arch, and the Gaines combustion chamber opens up further opportunities for the Consolidation engine. The application of the superheater results in increased capacity which corresponds, roughly, to a 25 per cent. larger boiler capacity than it was possible to provide in connection with saturated steam engines. The brick arches permit increased amounts of heat to be utilised from the fuel burned on restricted grate areas. It should be possible to build Consolidation engines with good steaming capacities and economical fuel requirements that can develop as high as 54,000lbs. maximum tractive effort.

An offshoot from the successful Consolidation freight engine is the 12-wheel or 4—8—0 type. This type has not been widely introduced. It has an undesirable ratio between total weight and adhesive weight. The increase in the length of boiler made possible by the four-wheel truck in place of the two-wheel truck of the Consolidation engine nets but little in the direction of increased boiler capacity. The increase in the heating surface of the boiler is at the wrong end. To improve the steaming capacity of the Consolidation engine it is necessary to introduce modifications at the firebox end.

The introduction of such modifications has resulted in the Mikado (2—8—2) type engine. By placing a trailing truck underneath the firebox better boiler construction becomes possible; also a decided increase in effective heating surface, a deeper throat sheet and wider water legs are secured. However, as large a proportion of the total weight of the engine is not utilised for adhesive purposes as with the Consolidation type. By moving the firebox behind the drivers, it also becomes possible to enlarge the boiler diameter, and to increase the relative diameter of drivers, thereby permitting of lower piston speeds. The general construction of the Mikado locomotive is such that it permits of very ample steaming capacity and thus of high sustained tractive efforts. The application of the superheater and brick arch has further increased its capacity in this direction. It is most admirably suited to haul slow maximum tonnage freight trains one day and fast trains the next, a condition frequently met in railroad operation.

The size of Mikado locomotives for most roads is principally limited by the allowable weights on drivers. It seems to be generally considered that an individual axle load of 60,000lbs. for the better conditions of roadbed, as they are met with to-day, is very nearly the largest permissible. If so, the Mikado engine, as far as size is concerned, has very nearly reached its limit, and the demand for still larger engines will

have to be met either by introducing another pair of drivers, making five pairs in all, or by resorting to the Mallet type. With their weight on drivers limited to about 60,000lbs. per pair, it is possible to build Mikados which have a maximum tractive effort of 60,800lbs. with very favourable sustaining qualities at high speeds. The utilisation of the superheater and brick arch in connection with the well proportioned boiler and efficiently designed engine make it possible for this size of locomotive to be operated without requiring excessive amounts of fuel so that one fireman can handle all that is needed.

To get still larger capacities than are provided by the Consolidation and Mikado types, the Decapod (2—10—0) and the Santa Fe (2—10—2) types are available. The Decapod (2—10—0) type, like the Consolidation and 12-wheel types, has limitations as regards boiler capacity, in consequence of which it is practically adapted to slow service only. Its high proportion of weight on drivers, giving it a high ratio of adhesion is of advantage for this kind of service. The Santa Fe type permits of better boiler proportions than those of the Decapod type, just as the Mikado is better than the Consolidation. The additional pair of drivers enables a tractive effort about 20 to 25 per cent. greater than can be secured from the Mikado engine. Allowing 60,000lbs. per pair, the maximum tractive effort possible should be about 73,000lbs. to 75,000lbs., barring cylinder limitations. Several engines of this type now in service deliver a maximum tractive effort of 71,000lbs. It is reported that they can be handled by one fireman without undue effort.

Locomotives with five pairs of coupled wheels have an exceedingly long rigid wheelbase. This would introduce many complications should they be placed on territories where track curvature is frequent or severe. Furthermore, the exceptionally heavy pressures on the main pins and the heavy reciprocating parts justify expectation of maintenance difficulties. The long wheelbase and the large number of heavy wheel loads in rigid order may be proportionately harder on the track than is the case with large Mikado engines.

Another type of engine which deserves consideration for freight service is the Mountain (4—8—2) type, which is similar to the Mikado in all its characteristics. Where fast freight service is abundant and high speed is frequent the additional advantages in guiding qualities secured by the four-wheel leading truck and the slightly increased boiler capacity are important.

The Pacific type engine for exclusive fast freight service, where grades are not severe and where this kind of service is heavy, is a very desirable type. A large number of these engines have been built for this service and are giving an excellent account of themselves.

The Mallet type offers quite as wide a field to choose from as the Pacific, Consolidation, Mikado, and Santa Fe types combined. Mallet locomotives have been built on both the compound and the simple principle. The wheel arrangement permits of a great number of practical combinations. The application of the superheater and brick arch, feed-water heater and reheater, together with well proportioned boilers and the compound feature has made possible units of large size and of good drawbar pull characteristics at different speeds. At the same time Mallets are economical in fuel consumption. The arrangement of the drivers in two independent sets, and the division of the total engine weight over these two sets permits readily of meeting track and axle load limitations. Hence these engines offer a large field from which to make selection when the restrictions of the permanent plant are such that they cannot be overcome except by heavy expenditures.

Mallet engines can be built to deliver a maximum tractive effort of 140,000lbs. This would mean engines with 10 pairs of drivers, each having an average load of about 60,000lbs. As long as 60,000lbs. remains the maximum average practical wheel load, while track curvature remains a consideration, and the gauge of the track remains at 4ft. 8½in., thereby limiting the height of the centre of gravity of engines, it is questionable whether an engine much larger than this can be built. It is not a size which has been reached to-day, although there are Mallet engines in service which have 10 pairs of drivers.

A large number of Mallet locomotives are in road and pusher service whose tractive effort working compound range from 73,000lbs. to 105,500lbs. They are meeting with success from the fuel, operating, and maintenance standpoints. The largest number of drivers under the engines referred to is eight pairs, the average weight per pair under the largest one being 58,560lbs. Hence, 105,500lbs. tractive effort is not far from the maximum possible with eight pairs of drivers allowing 60,000lbs. per pair.

The types of switching locomotives available range from the 6-wheel coupled to the 10-wheel coupled. Switching locomotives of five pairs of drivers have a rather long rigid wheelbase, perhaps too long for the average yard conditions as they exist on many roads to-day. Locomotives with four pairs of wheels have a more suitable wheelbase, and are capable of delivering comparatively high tractive powers. Locomotives of three pairs of drivers are the most universal in service to-day.

The Permanent Plant and its Relation to Motive Power Selection.—The permanent plant of a railway as related to the motive power is the track, bridges, passing sidings, terminal yards, engine terminals, including the roundhouses, turn-tables, coaling stations, watering cranes, ash plant, and sanding facilities, and the locomotive repair shops. It has been shown what a wide range of motive power is available from which selections may be made for any class of service. In order that the possibilities of this large field may be fully realised, it becomes necessary to study carefully the various changes in the permanent plant to be considered in connection with the introduction of different types and sizes of engines. Such a study will oftentimes show that improvements made to the permanent plant at limited costs will permit of utilising motive power which will effect a considerable saving in operating expenses, thereby fully justifying the expenditure.

The improvement of the track with a view of making possible higher train speeds and heavier axle loads is a complicated problem. Track improvements such as laying heavier rails, respacing of ties, increasing the carrying power of the sub-grade by drainage, deepening and improving the nature of the ballast, are continually under way. The tendency is to strengthen and improve track as rapidly as earnings will permit, so that full advantage may be taken of all that is offered in the way of possibilities to increase engine capacities and train tonnage. The state of good track to-day, laid with 90lbs. and 100lbs. rail, is such that it readily allows 60,000lbs. axle loads, which is about as high, on the average, as it is advisable to go. While the track may be such that, should heavy wheel loads be imposed, it would result in increasing the maintenance costs, the tendency may nevertheless be to improve this lighter track in the near future by introducing ballast and relaying the lighter rail with heavier. In such cases, and they are very prevalent, the present track conditions should not be permitted to limit the motive power sizes too greatly because of the economical advantages of increased train loads.

Bridges not only restrict the individual axle load, but also the total weight. Moderate expenditures in the direction of bridge improvement, plus the regular programme of bridge renewals and improvements, may permit of taking advantage of a type of locomotive which would effect economies in operating expenses that would more than pay for the unusual improvement expenses incurred.

Unless the yards and passing sidings are adequate to take care of longer trains, the improvements expected by the introduction of larger locomotives will not materialise and the operating expenses will show but little decrease. The long trains are apt to be tied up, and blockades will occur which are expensive as well as demoralising.

Except for side and overhead clearances, the coal chutes, watering cranes, sanding and ash-handling facilities, will have but little effect on the choice of new locomotives. Ash-pit construction may need a little modification to permit of heavier wheel loads. The roundhouse may be inadequate to permit of housing the larger engines suitably. The turn-table may be too short or too light to turn the heavier engines. Limited or inadequate locomotive terminals, in part or in whole, should not be permitted to stand in the way of introducing the most economical locomotive available. It is becoming more generally recognised that as motive power increases in size it becomes relatively more important

and economical to provide means at locomotive terminals whereby the turning of power is expedited.

It would be manifestly impractical for a railway to undertake to rebuild its entire shops for the sake of handling a very large engine of the Mallet type. As a rule, however, especially on the larger roads, the present shopping facilities are such that a railway, from this point of view, should find but few limitations to the size of locomotives it may find desirable to operate. Then again the adopted programme of shop facility renewals and modifications, continually necessary as business keeps growing and old parts of the shops depreciate, tends to take away from the seriousness of this consideration. Clearances through cuts, of water cranes, buildings, and other fixed structures along the right of way have some effect in determining the size of the engine to be handled in the yards.

The Relation of Operating Expenses to the Selection of Motive Power.—The effect of the selection of locomotives for passenger and switching service on operating expenses does not play as important a rôle as it does in the selection of engines for freight service. The choice of passenger and switch engines is determined very largely by imposed conditions resulting from circumstances peculiar to the nature of these two kinds of service. Larger and heavier switch engines are usually made necessary by heavier trains handled in the yards. The demand for larger and improved passenger engines results from the necessity of maintaining high speeds with trains which are growing in weight due to the introduction of steel equipment and more cars. It should be observed, however, that the economy of the various types of engines available, from the fuel, lubricating, and maintenance points of view, has an important bearing on the ultimate selection. That type and size of engine should be chosen which will operate with the least expense for fuel, water, and repairs, and which will keep as low as possible, consistent with the size of the engine in regard to the service requirements for the present and the future, the expenditures for improvement to the permanent plant.

In the selection of power for freight service, the effect of the various types and sizes on the operating costs should go a long way towards determining the most economical engine to choose. The largest part of the gross revenue of railways results from freight transportation, and the greatest proportion of their operating expenses are consumed in conducting this transportation. The nature of freight service permits a much greater flexibility as far as choice of the motive power is concerned. A study should be made to determine which type and size will effect the greatest net saving in operating expenses after deducting all overhead and additional maintenance charges resulting from the improvements necessitated by the introduction of the engine. Only by such a study as this in conjunction with considering the service conditions and the tendency of future development can the ultimate selection be made with any degree of correctness.

The items of operating costs and overhead charges which should be considered in such a study are the following: (*a*) Transportation expenses, fuel, water, lubricants for locomotives, other supplies for locomotives, enginehouse expenses, train supplies and expenses, enginemen's wages, and trainmen's wages. (*b*) Maintenance of equipment, locomotive repairs, and freight train car repairs. (*c*) Maintenance of way and structures, ballast, ties, rail, other track material, roadway and track labour, bridges, trestles and culverts, and buildings, fixtures, and grounds. (*d*) Overhead charges, interest on locomotives and improvements to permanent plant, depreciation of locomotives and improvements to permanent plant, and taxes and insurance on locomotives and improvements to permanent plant.

To attempt to discuss within the limits of this paper the effect of locomotive types and sizes on each one of the items of railway expenses concerned would be impossible. Wellington, Webb, and Henderson have formulated many of the principles involved, and reference to the works of these men will reveal considerable valuable data and information on this subject. The statistics kept by the individual railways will furnish additional information necessary for the analysis. The application of logical reasoning and the use of recent data established by both laboratory and service tests will further aid in making correct comparisons. The suggestions regarding the various items of expenses and their relation to motive power selection will therefore be general and seek rather to point out the inherent tendencies of these expenses and their importance.

Fuel is the largest single item of locomotive operating expenses and therefore the most important. The fuel consumption may be divided into the following classes: (*a*) fuel used while actually working on the road; (*b*) fuel used while drifting and waiting; and (*c*) fuel used at terminals for firing up. As locomotives grow larger their fuel consumption per unit increases, but not nearly in proportion to the increase in their size. It does not take very much more coal to fire a large locomotive than a small one. The fuel losses of a large locomotive due to radiation while waiting or drifting are but slightly larger than those of a smaller locomotive. The increase of fuel consumption of large saturated simple steam engines when working at their full capacity is more nearly in proportion to the increase in their size. The introduction of the superheater, feed-water heater, and reheater, the increase in heating surface of the boiler, the brick arch, the utilisation of compounding in large engines of the Mallet type, application of improved valve gear and compound air pumps, and more careful attention to the design of steam passages and steam engine efficiency have accomplished remarkable results in keeping the fuel consumption of large locomotives down so that their consumption per train-mile is increased but slightly over that of the recent types of smaller saturated steam locomotives.

Numerous tests and service records have revealed that large superheater Mikado locomotives which have been placed in service recently haul trains of 45 and 50 per cent. greater tonnage with the same amount of coal that was formerly consumed by the Consolidation locomotives they replaced. Even the coal consumption of Mallet engines with grate areas up to 100 sq. ft. has not grown in any way proportionate to the increase in their hauling capacity. Modern engines when running at shortened cut-offs over those portions of the road other than the ruling grades exhibited a still greater economy than when working on the heaviest grades. Some service tests of recently built Mikado engines on the Delaware, Lackwanna, and Western Railroad clearly demonstrated these facts. Their economy in fuel consumption as compared with that of the old Consolidation type, both operating over heavy grades at full load, was 20 per cent. The economy effected over easy grades while running at shortened cut-offs was 39·3 per cent., almost twice as much. The average was 29·1 per cent.

The conclusions to be reached in regard to the fuel consumption of larger locomotives equipped with those fuel-saving devices which have proved their merit is that it increases but slightly as their hauling capacities increase. It depends of course largely upon the size of locomotives in service as to what the actual increase will be on the train-mile basis over the consumption of the old engines, and this must be taken into consideration.

The same things that are true of fuel consumption are true of water consumption, only perhaps more so, especially with superheater engines. Water economy increases but slightly with the increase in locomotive sizes.

It is safe to conclude that the cost of locomotive lubrication increases more or less directly in proportion to the increase in the size of the locomotive as reflected by the wheel and cylinder arrangements. Other supplies for locomotives are affected slightly, if any, by an increase in locomotive capacities.

As the size of engines increases the cost of engine-house expenses per engine handled increases. However, as the size of engines increases the number handled at the terminals decreases. This decrease should approximately counterbalance the increase in cost per engine handled. The item of train supplies and expenses per train-mile is affected but slightly by a decrease in train mileage.

The cost of locomotive repairs does not increase in direct proportion to the increase in hauling capacity. Under modern conditions it will perhaps be safe to assume that about 60 per cent. of the total cost of locomotive repairs varies directly as the weights of locomotives increase.

The item of freight train car repairs per train-mile increases slightly more than in direct proportion to the increase in the number of cars hauled in the longer trains by the larger locomotives. Improvements in car construction, however, are rapidly counteracting this tendency.

General observations seem to indicate that about 40 to 50 per cent. of the cost of maintaining track per train-mile varies directly with the average increase of weight on drivers. The many improvements in track construction continually under way, the introduction of treated ties, heavier rails of improved steel, and better drainage facilities all help to reduce to a minimum the effect of heavier power on the road bed. The improvements to bridges, buildings, and structures, such as roundhouses, turntables, and shops, the lengthening of passing sidings, and the extension of yard facilities have a further effect on the cost of maintenance of way and structures as related to the increase of motive power sizes. The overhead charges include interest, depreciation, taxes, and insurance, and should be carefully estimated.

Final Determination of Most Economical Locomotive to Adopt.—Taking each one of the items into consideration, estimating the reduction in train mileage effected by each type, the gross savings effected, based on the amounts of business on hand or in sight, and deducting therefrom all overhead charges arising from the additional improvements necessary to make the operation of the different types of locomotive under comparison practical, will reveal which particular locomotive is the most economical in size and type.

As far as a standard engine of any kind for an entire road is concerned the general conditions obtaining will have some bearing. A road may, for instance, be composed partly of divisions whose grades are moderate and partly of divisions whose grades are severe. If the variations are not great a compromise standard might be adopted. If, on the other hand, there is a large difference, it may be wiser to seek to establish two or three standards and confine them to their particular territory, with a view to getting the maximum efficiency from every portion of the property. Then again there are many shorter territories, such as pusher grades and divisions through mountainous country, the motive power selection for which is a distinctly local problem. In every case, whether it is the broad problem of establishing standards for the entire system, or selecting an engine for a local territory, the problem might well be reduced to an economic study, comparing several available types and sizes, the extent of the improvements necessary to make their operation practical, and the net savings which it is estimated will be effected by their introduction.

Summary. — In designing new locomotives all of the conditions must first be analysed and then the design made to suit them. The actual design of the engine finally chosen may be approached with confidence because of accumulated knowledge and experience. Due to the great possibilities of favourably effecting operating results by building locomotives which are exactly suited to their work, a study of the conditions becomes vitally important. To show what these conditions are has been the object of this paper. The fact that the most powerful locomotives of most approved design are also the most economical should be more generally appreciated. It is to be hoped that the future will see more advantage taken of the modern locomotive in accordance with its possibilities in relation to grade revision and its ability to reduce operating expenses to a minimum. The ultimate benefits which will result will certainly be justified to the fullest extent.

MODERN METHODS OF INDIRECT LIGHTING.

AN interesting paper on this subject by Mr. F. W. Willcox and Mr. H. C. Wheat was read at a recent meeting of the Illuminating Engineering Society. At the outset the authors remarked that the artificial production of light was perhaps the most inefficient and wasteful process to be found in any branch of engineering or science. This fact was the strongest argument for the necessity for "efficient" lighting, *i.e.*, for using such arrangements of artificial light sources as would most economically meet the demand for properly distributed light. In the case of lighting the term "efficiency" must be used in a broader sense of general visual efficiency, by which was meant the effectiveness of the illumination secuied in enabling things to be seen easily and in comfort. The success of indirect lighting awaited the development of new and improved appliances. This result was secured by the introduction of the system known in America as "eye-comfort," and in England as the "eye rest" system of illumination. In this system there was employed a fixture in the form of an inverted bowl suspended from the ceiling of the room, and containing highly efficient and powerful reflectors of special mirror glass construction. The reflectors were known as "X-ray," and consisting of blown-glass blanks of correct form, which were in one piece and fire-glazed. These blanks were backed with pure silver, put on by a special process, and this in turn was covered with an elastic enamel to protect and preserve it. The blanks were given a number of flutes and corrugations in order to prevent striations. Of 734 lumens generated by the lamp, 612 were yielded from the reflector, which equalled an efficiency of over 83 per cent.—a much higher efficiency than was given by any other reflector with which the authors were conversant. It would be appreciated from the foregoing description that the reflectors were opaque, so that opaque containers were also used. The latter usually took the form of bowls, which might be of metal, wood, glass, earthenware, plaster, &c., so that not only was there the possibility of an enormous number of different designs, but also a large selection of material from which to execute them.

The various systems of artificial lighting in use were next compared by the authors, including (*a*) direct lighting systems in which the greater part of the illumination was received directly from the light units or sets of lamps and reflectors; (*b*) direct lighting, in which the greater part of the illumination was received directly from a light source enclosed in diffusing globes; as, for example, Holophane spheres, Holophane bowls, and Alba spheres; (*c*) semi-indirect lighting, in which the light was partly transmitted directly from the lighting units through a diffusing medium and partly indirectly by reflection from the ceiling or other surface; and (*d*) indirect lighting, in which no light was received directly on the illuminating plane, but only indirectly through reflectors from a second surface or body. In the form of indirect lighting considered under this heading the light was directed away from the objects to be illuminated and thrown upon the ceiling, from which it was reflected upon the working plane. While on the score of pure physical efficiency in lumens per watt, the last system might stand below the others, yet in point of general visual efficiency its general results were comparable, and in many cases superior, to the other systems.

Even the physical efficiency of indirect lighting systems was often considerably ahead of that of installations which it replaced, so that the adoption of the indirect lighting system in numbers of cases actually reduced the energy consumed. Glare was undoubtedly reduced to the minimum. The lamps themselves were entirely hidden, and the greatest surface brightness, that on the ceiling, was very much lower than with any other form of lighting. The very large surface of the ceiling acted as a virtual source of lighting, giving almost perfect diffusion with an entire absence of the uncomfortable effects associated with glare. As regards shadow effect, the indirect lighting system stood pre-eminent. Shadows were less dense, and their edges softer. It would be a mistake, however, to assume that this lighting was shadowless, as that would make it objectionable. It cast shadows of a character which avoided their disadvantages, and secured the advantages by preventing any flat effect that might occur under other systems of indirect lighting such as cove-lighting. In evenness of illumination the indirect system surpassed all other systems, and properly installed gave the best results from the fewest number of points. It was one of its important advantages that it required much fewer outlets than the direct system. The difference was that with the indirect system of illumination the illumination of a room was treated as a whole, while with direct lighting it might have to be treated in parts or sections. As regards comfort and agreeableness of lighting, the best results of all were obtained by the indirect system.

COMBINED INTERNAL FLUE AND WATER-TUBE BOILER.

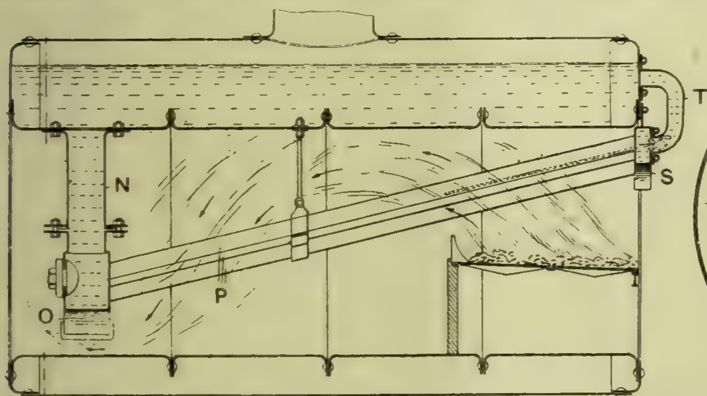
The accompanying sectional views show a construction of combined internal flue and water-tube boiler, the invention of Mr. L. Haubentaller, of Ujszasz, Hungary. The boiler is provided with an internal flue in which is arranged at the front end the furnace grate and at the rear end a tubular extension N, inwardly and downwardly directed and connected by means of a flange with the water chamber O. A number of inclined water tubes P open out in the water chamber O, and are connected to a second water chamber S. This chamber is secured to the front wall of the boiler, and is in communication, by means of a bent pipe T, with the upper portion of the water space of the boiler. The water tubes P are supported in their middle by means of a suspended supporting member. The cleaning of the rear water chamber O and of the water tubes is effected through openings which are closed in the usual manner by means of caps.

COBALT ALLOYED WITH CHROMIUM AND OTHER METALS.*

BY ELWOOD HAYNES.

For a number of years I have made experiments with a view of finding certain metallic combinations or alloys which would not only resist oxidation and other harmful influences, but would also possess valuable physical properties which would render them fit for special service. The first decisive step made in this direction was the discovery of an alloy of nickel and chromium in 1898. Immediately following the discovery of the nickel-chromium alloy, I produced an alloy of cobalt and chromium.

As early as 1907 I made alloys or combinations of cobalt, chromium, and tungsten; cobalt, chromium, and molybdenum; and cobalt, chromium, tungsten, and molybdenum.



Combined Internal Flue and Water-tube Boiler.

I have made alloys of cobalt and chromium containing zirconium, tantalum, thorium, titanium, vanadium, &c. I have also added to the cobalt-chromium alloys the non-metallic elements, carbon, silicon, and boron. Some exceedingly interesting results have been obtained from these various combinations, and while further investigation is necessary in order fully to determine their chemical and physical properties, a number of them have shown interesting economic possibilities.

The preliminary fusions were made in graphite crucibles by means of a furnace operated by natural gas. I was later obliged to use crucibles of a special composition, not only to avoid the contamination of the metal by carbon from the crucible, but also because they proved more reliable under long-continued heating than those made of graphite.

Tungsten alloys readily with chromium and cobalt in all proportions. When added in small quantities to the cobalt-chromium alloy, it seems to have little influence on the properties of the combination, but if the proportion rises to 2 or 3 per cent. a notable effect is produced. Generally speaking, the cobalt-chromium alloy becomes harder and more elastic, especially if it contains a small amount of carbon, boron, or silicon.

The following experiment shows the effect of melting the alloy in a graphite crucible: Ninety grams of cobalt, 6·3 grams of tungsten, 18 grams of chromium, together with a small quantity of calcium silicide, were introduced into a graphite crucible. The resulting alloy was very hard, and the crucible much eroded on the inside. The bar could be slightly flattened at one end, and after being made into a cold chisel, showed remarkable qualities. It would not only scratch glass, but also quartz crystal. It was quite tough at ordinary temperatures, and would cut small chips or shavings from a piece of stellite. At a bright yellow heat it showed signs of fusion, and became covered with a skin of oxide.

An alloy was made by melting the following in a special crucible: Cobalt rondelles, 80 grams; chromium, 20 grams; tungsten, 7 grams; calcium silicide, 10 grams; and calcium carbide, 5 grams. As soon as the above were melted, the crucible cover was removed and 15 grams of an alloy of cobalt and boron was introduced. The crucible lid was then replaced and the heating continued. A heavy, thick slag formed, which was removed before pouring the metal. The resulting bar was very hard and elastic, but only drew slightly under the hammer and then broke. A cold chisel made from the cast metal cut iron readily. The bar was broken and remelted with about one-third of its weight of an alloy of cobalt, chromium, tungsten, and carbon. The result was a fine-grain alloy which was very elastic, and would draw out to a considerable degree under the hammer without checking. Its elastic limit must have been very high, since when it broke the pieces were thrown violently.

Taking the alloy of chromium and cobalt as a basis, and holding the proportion of chromium at 15 per cent. of the entire mixture, it was found that the alloy gradually increased in hardness with the percentage of tungsten. When the quantity of tungsten rises to 5 per cent. the alloy becomes distinctly harder, particularly when forged under the hammer. When the tungsten reaches 10 per cent. the metal still forges readily, and a tool formed from the alloy takes a fine cuting edge. This alloy is suitable for both cold chisels and woodworking tools. When the tungsten rises to 15 per cent. the metal can still be forged, but great care is necessary in order to avoid checking. This alloy is considerably harder than that containing 10 per cent. of tungsten, and is excellent for cold chisels. When the tungsten rises to 20 per cent. the alloy is still harder, and can be forged to a small extent. It makes good lathe tools for cutting steel and other metals at moderate speeds. When the tungsten rises to 25 per cent. a very hard alloy results, which cannot be forged to any extent, but casts readily into bars which may be ground to a suitable form for lathe tools.

These tools have shown great capabilities, particularly for the turning of steel, since they are very strong, and retain their hardness at speeds which almost instantly destroy the cutting edge of a steel tool. The tungsten may be still further increased to 40 per cent. and the alloy will retain its cutting qualities, and for turning cast iron this alloy answers even better than that containing 25 per cent. When the tungsten reaches 40 per cent. or more the alloy becomes so hard that it will not only scratch glass, but will readily scratch quartz crystal. A small drill made of this material drilled a hole through the wall of a glass bottle without the addition of any liquid or other lubricant.

A $\frac{5}{8}$in. square cast bar, when ground to a suitable edge, was set in a toolholder attached to a lathe. The workman who had operated the lathe had been able to turn to form 26 cast-iron wheels in 10 hours with a steel tool of the same size. The stellite tool turned 49 of these wheels to form in the same time. The steel tool was ground 50 times during the operation, while the edge of the stellite tool was dressed slightly by a carborundum whetstone, after its day's work was completed. A set of steel cutters, placed in the boring head of a cylinder boring machine, was able to bore from

* Paper presented at the Cleveland meeting of the American Institute of Mining Engineers.

27 to 28 holes in 10 hours. These cutters were replaced by others made of stellite, which performed the work in 3 hours and 20 minutes, or a little more than one-third the time. Not only was the speed of the mill doubled, but the feed also, and notwithstanding this severe ordeal, the stellite cutters were only slightly worn, while it would have been necessary to regrind the steel cutters at least two or three times for the same service at slower speed. Some remarkable results were obtained in the turning of steel on the lathe. For example, a cylindrical bar of annealed nickel-chrome steel, about 2·5in. diam., was placed in a lathe and turned with a steel tool at about as high a speed as the steel would permit without burning. The steel tool was then replaced by one of stellite, and the speed at the same time increased to $2\frac{2}{3}$ its former speed. The stellite tool retained its edge under these severe conditions, and produced a shaving weighing 1·2lbs. in 30 secs. Just what the effect of the alloy will be in machine shop practice is at present somewhat difficult to determine. In my opinion, however, it will not fully supersede high-speed steel in the machine shop, but in cases where rapid work is the main consideration it will doubtless replace high-speed steel.

When molybdenum is added to a 15 per cent. cobalt-chromium alloy the alloy rapidly hardens as the molybdenum content increases, until the content of the latter metal reaches 40 per cent., when the alloy becomes exceedingly hard and brittle. It cuts keenly and deeply into glass, and scratches quartz crystal with ease. It takes a magnificent polish, which it retains under all conditions, and on account of its extreme hardness its surface is not readily scratched. When 25 per cent. of molybdenum is added to a 15 per cent. chromium alloy, a fine-grained metal results, which scratches glass somewhat readily and takes a strong, keen edge. Its colour and lustre are magnificent, and it will doubtless find a wide application for fine, hard cutlery. It cannot be forged, but casts readily, and its melting point is not abnormally high.

If carbon, boron, or silicon are added to any of the above alloys, they are rendered much harder, though their effect is not always desirable, since they tend to render the alloys more brittle. If either tungsten or molybdenum is added to a cobalt-chromium alloy containing 25 per cent. of the latter metal, the hardness of the alloy is rapidly increased. When the percentage of tungsten, for example, reaches 5 per cent., the alloy can be readily forged, and forms an excellent combination for wood-cutting tools, such as chisels, pocket knives, &c. When molybdenum is added to the same mixture of chromium and cobalt, much the same effect is produced, though, generally speaking, a smaller quantity of molybdenum is required to produce a given increase in hardness. In some instances I have found it advisable to add both molybdenum and tungsten to the cobalt-chromium alloys. Generally the colour and lustre of these alloys, after polishing, are magnificent, and they seem to resist atmospheric influences equally as well as the binary alloy of cobalt and chromium.

The Society of Engineers.—The third annual general meeting of this society was held at the society's offices, Westminster, on Monday, December 9th, Mr. John Kennedy, President, being in the chair. The report of the scrutineers of the postal ballot for the election of Council and officers for 1912 showed that the following had been duly elected: President, Arthur Valon; vice-presidents, H. C. H. Shenton, Norman Scorgie, T. E. Bower; members of Council, Henry Adams, C. T. Walrond, Percy Griffith, H. C. Adams, J. R. Bell, S. Cowper-Coles, H. P. Maybury, B. H. M. Hewett, F. H. Hummel, G. A. Becks; associate member of Council, R. J. Simpson; hon. secretary and treasurer, D. B. Butler. It was announced that premiums for papers read at meetings and published in the "Journal" during 1912 had been awarded as follows: The President's Gold Medal to Mr. W. P. Durtnall, for his paper on "The Generation and Electrical Transmission of Power for Marine Transportation." The Bessemer Premium, valve £5. 5s., to Prof. Herbert Chatley, for his paper on "Resistance to Rolling." The Clarke premium, value £5. 5s., to Mr. Gerald O. Case, for his paper on "Ligno-Concrete." The Bernays' Premium, value £2. 2s., to Mr. J. P. Harris, for his paper on "The Construction of a London County Council Low Level Sewer from Battersea to Deptford." A Society's Premium, value £2. 2s., to Mr. P. J. Waldram, for his paper, entitled, "Test Deflections in Reinforced Concrete."

THE BEST SPEEDS OF WOODWORKING MACHINES.

THE speed at which machines should run to give the best results is a problem that operators should understand. To prove that it is an intricate, or at least an undetermined matter, we need only refer to the diversity of opinion among mechanics, and the want of any opinion at all with a great many.

If the speed of a machine could be calculated from that required for the cutting edges alone, we should have a general rule to apply, but the limit of speed is more frequently taken from the condition of the spindles and bearings than from the cutting action. Cutterheads more than 4in. diam. can generally be moved as fast as the edges require to run to give a good result, say, within 5,000 revs. per minute or 5,000ft. of movement with the edges. But when the cutterhead is smaller, the spindles are not diminished in the same ratio, and the speed must be slower.

The cutting movement should, as far as possible, be a basis for estimating speed, instead of the number of revolutions made by a spindle. A cutter on a 3in. head, making 4,000 revs. per minute, is only moving as fast as one on a 6in. head at 2,000 revs. per minute, and still it is quite common and a habit hard to avoid to consider all spindles wanting a common speed from 3,000 to 5,000 revs. per minute without considering the movement of edges.

Perhaps as good a rule as can be used is to assume a 4in. cutterhead to make 4,000 revs. per minute as a base or unit of speed. This makes approximately 4,000ft. a minute of cutting movement; then increase 500ft. a minute for each inch of diameter added to the cutterhead. This makes, at 10in. diam., a speed of 7,000ft. a minute, and for 16in. diam. 10,000ft. a minute, which could then become a constant for all larger diameters. This, it must be remembered, is assumed for strong cutterheads of forged or malleable iron, steel, or brass, and not cast iron, which should not be used for high speeds.

Reversing this rule, from 4in. diam., with 4,000ft. of cutting movement, deduct 750ft. of the movement for each inch of diameter the heads are reduced. This, at 1in. brings the cutting speed to 1,750ft. a minute, with 7,000 revolutions of the spindle, a practical limit.

Boring machines, to operate screw-bits, should run from 1,000 to 2,000 revs. per minute, according to the kind of wood or the size of bits used. For all reciprocating machines there is a general rule that applies, which is to run them as fast as they will stand. In other words, their work always demands more speed than it is possible to have. This is certainly not a very comprehensive rule, but another one, infinitely better, is to use them only when they cannot be avoided, no matter to what purpose they are directed. For ordinary reciprocating machines the following list of speeds is given:—

	Revolutions per minute.
Resawing machines	250 to 300
Scroll-saw machines	300 to 400
Jig-saws with spring tension	500 to 800
Jig-saws with unstrained saw	800 to 1,500
Mortising machines with movable table	300 to 450
Mortising machines with chisel feed table	250 to 350
Mortising machines, heavy, for car work	200 to 300

Circular saws can be driven at a speed of 7,000ft. to 10,000ft. a minute. The manner in which they are hammered has much to do with the speed at which they may run, and often when a saw becomes limber and deviates it is a fault of the hammering instead of the speed. When slack on the periphery they will not stand speed, and become weaker and bend more readily when in motion than when still.

On the contrary, if properly hammered, a little "tight," as it is termed, on the periphery, they become more rigid when in motion up to a certain limit. The cause of this is that steel is elastic, and is stretched by the centrifugal strain in proportion to the speed, which is greatest at the teeth and diminishes to the centre. If saws have a tendency to spring, also want of rigidity, it can be remedied in most cases by hammering.

Cutting wood is like cutting iron; hardwood cannot be cut at as high a speed as softwood. Anyone who has had experience in working boxwood, cocoa rosewood, or lignum-vitæ, will have noticed that a high speed soon destroys edges by overheating, especially with boring or turning tools that act con-

tinuously. The use of these hard varieties of wood is, however, so exceptional that the matter need not be discussed here further than to say that a moulding or planing machine that is to run mainly upon walnut, ash, oak, or other hardwood will give better results if run a fourth slower than for softwood.

Approximate Speeds, etc., of Cutter Heads.

Diameter of cutter-head in inches.	Feed of cutting movement per minute.	Approximate number of revolutions a minute.	Average speed of bearing surface in feet.	Ratio of movement in the bearings.
1	1,750	7,000	875	8
2	2,500	5,000	937	9
3	3,250	4,333	1,083	10
4	4,000	4,000	1,125	11
5	4,500	3,600	1,125	11
6	5,000	3,333	1,145	11
7	5,500	3,142	1,277	13
8	6,000	3,000	1,406	14
9	6,500	2,880	1,444	14
10	7,000	2,880	1,445	14
11	7,500	2,706	1,450	14
12	8,000	2,666	1,465	15
13	8,500	2,615	1,525	15
14	9,000	2,576	1,541	15
15	9,500	2,533	1,551	15
16	10,000	2,500	1,512	15
17	10,000	2,352	1,470	15
18	10,000	2,222	1,417	14
19	10,000	2,105	1,382	14
20	10,000	2,000	1,370	14
24	10,000	1 666	1,250	13
30	10,000	1,333	1,083	11
36	10,000	1,111	987	10
40	10,000	1,000	1,000	10

The cylinders of planing machines, being strong and safe, and the rate of feed required as much as possible, they can be run at a speed one-fourth more than that given in the table. Line shafting should in all cases run as fast as the bearings will stand with safety; 200 revs. to 250 revs. per minute for 3in. shafts and 250 revs. to 300 revs. per minute for 2½in. shafts make a good rule, to be modified, of course, by the kind of bearings that are used. Countershafts can run three times that fast.—"Wood Craft."

Reducing Gears for Ship Propulsion.—According to Mr. Herbert Rowell, of Messrs. R. & W. Hawthorn, Leslie, & Co., his firm, so far back as 1897, constructed a number of paddle steamers fitted with reducing gear, for the Chinese Eastern Railway Company for service on the Sungari River. As the draught permissible was extremely limited, and a number of heavy barges had to be towed, the conditions could not be fulfilled with ordinary paddle machinery. Mr. Rowell therefore submitted in February of that year a proposal, which was accepted, for propelling the vessels by means of triple-expansion machinery of the torpedo-boat type, placed athwartships, working at 150 revs., and driving the paddle wheels, 15ft. in diam., at 28 revs. per minute, by means of helical gearing working in enclosed oil-baths. Fifteen of these vessels were built at that time, and gave excellent results on service.

Accidents in Mines. — Part two of the general report on mines and quarries in the United Kingdom for the year ended December 31st, 1911, has just been issued as a Blue Book. It states that the total number of persons employed was 1,179,101 (1,096,238 at mines and 82,863 at quarries) or a net increase of 15,181 persons, as compared with the preceding year. There were 1,349 separate fatal accidents, causing the loss of 1,407 lives, a decrease of 495 fatalities on the year preceding. Commenting on the gain in safety over a long period of years, the report says, "the death-rate per million tons of minerals raised at mines under the Coal Mines Regulation Act during 1911 was 4·42, as compared with 19 for the year 1851. The death-rate per million tons of coal only for 1911 was 4·47. The total number of persons injured by accidents disabling them for more than seven days at all mines and quarries was 173,549, compared with 165,813 for 1910, an increase of 7,736.

ELECTRIC LIGHTING DATA.

In the course of a paper read before the National Electric Light Association, Mr. Ralph Beman presented the following tables of data relating to electric illumination of offices, works, factories, &c. Table I. gives the foot-candle intensities for various classes of service, and Table II. utilisation factors, a diagram also being included for approximate field work in the selection and placing of equipment. Having decided the average intensity, which in turn determines the total light flux on the plane considered, the next step is to find what the total flux generated by the lamps must be. This depends upon the efficiency of the system or the ratio of lumens effective to lumens generated. Utilisation efficiencies for different systems of light may be considered approximately as given in Table II. These tables have been

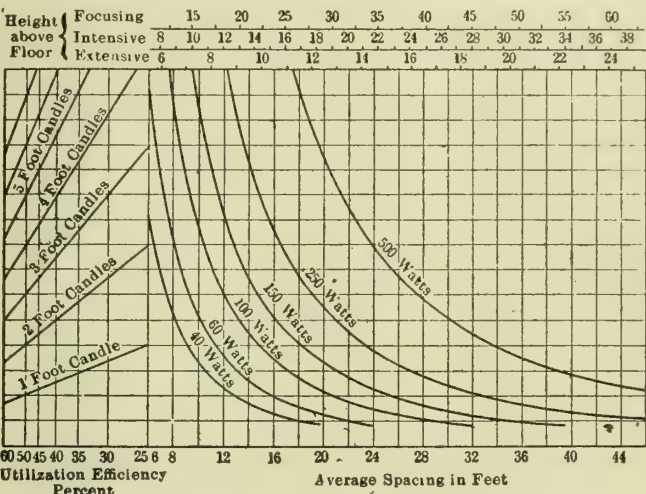


CHART FOR APPROXIMATE CALCULATIONS OF ILLUMINATING EQUIPMENT.

compiled with the idea of being representative of results which may be obtained with new reflectors and lamps operating at rated efficiencies.

TABLE I.—*Foot-Candle Intensities recommended for Various Classes of Service.*

Art Gallery (walls)	5·0
Automobile.	
Showrooms	5·0
Billboard	8·0
Card Room (tables)	3·0
Courts.	
Tennis	7·0
Draughting Room	8·0
Factory.	
General lighting (where individual drop lights are provided)	1·5
General lighting (where no individual lights are provided)	4·0
Local bench illumination	4·0
Gymnasium	2·5
Hotels.	
Bedroom	2·0
Corridor	1·0
Dining room	2·0
Lobby	2·0
Writing room	3·0
Library.	
Stock room	1·5
Reading room (with no local illumination supplied)	3·5
Reading room (with local illumination supplied)	1·0
Office.	
Desk	4·0
General (no drop lights)	4·0
General (with drop lights)	1·5
Show Window.	
Dark goods	20·0
Light goods	12·0

Store.

Clothing	6·0
Furniture	3·5
Grocery	4·0
Hardware	3·5
Shoes	4·0
Warehouse	1·0

TABLE II.—*Utilisation Factors.*

Unit.	Walls.		
	Light.	Medium.	Dark.
Prismatic glass	60	50	40
Opal or milk glass	50	42	33
Decorative or art glass	30	25	20
Semi-indirect	40	35	30
Indirect	Average value 30		
		Wide Angle	Narrow Angle
Steel*	—	58	50

*Values for steel will vary 10 per cent. either way, depending upon conditions. They hold only when ratio of mounting height to smallest dimension of room is not greater than 1 : 2.

The use of the chart may be illustrated by an example. Assume a store requiring an illumination of three foot-candles and that prismatic glass reflectors are to be used. With medium walls take the utilisation efficiency as 50 per cent. Using the left-hand portion of the diagram, find the vertical line corresponding to 50 per cent. efficiency and follow it upward till it intersects the oblique line marked 3 foot-candles. If one follows the horizontal line passing through this intersection over to the other portion of the diagram, it will be found that it intersects the curves representing the several units in as many points. The abscissas of each of these points give the spacing necessary to obtain the given intensity with each unit. In the case in hand 40-watt lamps should be spaced at intervals of 7½ft., 100-watt units at 12ft., 500-watt units at 28ft. The size of unit will be determined by the size of room and diffusion desired. The proper height above working plane can be read from the upper scales. Types of distribution will be chosen according to the ceiling height. The use of the two tables and the chart enables one to specify size, spacing, height of suspension, and light distribution from the unit, which in cases of uniform illumination is usually sufficient.

Mining of Tin Ores.—At a meeting of the Institution of Mining and Metallurgy held in London on the 19th inst., three papers were contributed in connection with the mining of tin ores. The first of these was by Mr. W. F. Wilkinson, the principal of the School of Mines, and dealt with the "Dressing of Tin Ores in Cornwall." Many of the mines still working tin ores seem to have been working under unsatisfactory conditions, and no very close check has been kept upon their methods of concentrating the "black tin" from the ore. This washed residue is of very indefinite value as regards actual tin content, which is usually determined by the miner's method of vanning on a shovel, and this is liable to great variation according to the class of ore treated. In this way the present great loss entailed in the defective treatment by ancient machinery is to a large extent obscured, so that the reported recovery of 90 per cent. of values resolves itself into as low a figure as 60 per cent. when tested by modern assay means. The author described some tests made at the School of Mines with modern plant which is expected to make a considerable improvement in the amount of metal recovered as tin concentrate. The second paper by Mr. H. B. Rawlings, described the "Direct Volumetric Determination of Tin," by a method worked out in Cornwall to give rapid and accurate results on all grades of tin ore. Mr. R. T. Hancock contributed "Notes on the Valuation of Nigerian Tin Concentrate," which as collected in the Willoughby tin ore dresser varies in actual metal content from 40 to 74 per cent. He described a method of easily determining the proportion of worthless black sand present in the "black tin," and which is used as an equitable basis of purchase from the tributers who wash the ore free from quartz in sluices.

PROGRESS OF WORK ON BORONISED COPPER.*

BY DR. E. WEINTRAUB.

THE process of boronising copper was merely the result of a lucky idea which forced itself upon me through experimentation in a totally different line, viz., that of preparing the element boron in a pure state, a line of work which was begun primarily for the purpose of testing whether boron would be an appropriate substance for incandescent lamps.

The story is very short. After having isolated the element boron I was struck by the great affinity displayed by it toward practically every known element, whether metalloid or metal, but I was no less impressed by the apparent lack of affinity between boron and copper, even at the melting point of the latter. I was carrying out the deposition of boron from boron chloride and hydrogen between water-cooled copper electrodes. Boron would deposit and grow on copper electrodes, but the latter would not combine with the boron, and any copper mechanically adhering to the boron could be easily washed off with dilute acids.

I had often heard that it was difficult to produce cast copper mechanically sound and of high electrical conductivity, and how the accomplishing of this would be desirable for electrical and other work. I said to myself that since boron has such a high affinity for oxygen, nitrogen, and oxygen-containing gases, which were probably, in one way or another, the cause of the difficulties in copper casting, and as boron, on the other hand, apparently had no affinity for copper, it was very probable that boron would be the natural deoxidiser for copper. I thought it might be worth while trying this out, but so many things look good in theory and yet do not work out in practice, and it is so hard to tell beforehand which one of a number of good ideas will work and which will be a sore disappointment, that, under the pressure of other work, I let this idea linger in my mind a number of months before I actually tried it, and then one day, when there was, luckily, a lull in other work, I asked my assistant, Mr. Kroner, to try to add a small percentage of amorphous boron (boron suboxide) to copper, and see what luck he would have. He added about 0·1 per cent., and after a short time brought me a sample bar, which looked good. The same measured up to 94 per cent. conductivity of Mathiessen standard.

The first simplification consisted in the substitution of boron suboxide flux for boron suboxide. Boron suboxide is made by reducing boric anhydride with magnesium, aluminium, or an alkali metal, and chemical treatment of the reaction product. For copper casting it is, however, unnecessary to treat the product as the ingredients of it (excess of boric anhydride and of borate) outside of boron suboxide are harmless or even useful in diluting the active agent. Of this boron suboxide flux 0·75 to 1 per cent. has to be added (equivalent to 0·08 to 0·1 per cent. of boron suboxide).

This is the flux at present used. However, any material which contains boron in a state of oxidation below that of boric anhydride is a flux for copper casting. Among other compounds of boron which satisfy this condition I mention boron carbide or any alloy of carbon and boron.

In order to better make the boron react on the copper or rather on the gases in the copper, I thought it would be best to superheat the copper, and I did that, although I was told that this is equivalent to ruining the metal. The copper, I was told, would "burn." The result was as I expected.

After the process had been made to work many directions presented themselves for further investigation. First and perhaps the most important from the point of view of pure investigation was the question of what the boron flux actually does. We have no reason to doubt that the boron reduces some gas in the copper, which is either oxygen itself or contains oxygen; it would be of great interest to ascertain the exact nature of the gas and the quantitative relations in the action of boron. We have not done this. Another line was to study the deoxidation of copper alloys by boron. We have done a little on that, and have ascertained that all the copper alloys containing the elements, zinc, tin, lead, greatly benefit by being deoxidised by boron, but we have not done

* Abstract of paper read before the American Institute of Metals.

as much in this direction as we would like and as we eventually will.

There remains for me to give you some details of how the process of boronising copper is carried out, and what precautions are to be taken in order to secure a good casting. The boron suboxide flux can be added to the copper in different ways, which are equally good. In the Lynn Foundry our pots contain about 125lbs. of metal, and up to the present coal furnaces have been used. The method used in the Lynn Foundry consists in mixing half of the boron flux to be added with charcoal, putting it on the bottom of the pot and melting the copper down. When the copper has reached the necessary temperature (the copper can be heated too low but not too high), the pot is taken out, the slag skimmed off, and the second half of the boron flux added and thoroughly stirred in. After a minute or so the slag comes up to the surface in the form of fused lumps, and is skimmed off, and the melt is cooled down by adding gates or risers until the proper pouring temperature is obtained.

In case a reverberatory furnace is used, as in Schenectady, the procedure usually followed is to put the flux in the ladle pot on the bottom, pour the copper over it, and stir thoroughly. The skimmer and stirrer are preferably not of iron, since it is difficult to avoid a solution of a slight amount of iron in the copper and a resulting lowering of conductivity. If done very carefully the amount of iron would probably be very small, but we did not find it practicable to trust the foundry men with an iron skimmer or stirrer. Heavy graphite stirrers and skimmers, made of Acheson graphite, have proved sufficiently rugged for use, and are being constantly used in the foundry.

The boronising process delivers a good metal, and the production of a good casting depends now on the same factors as in other metals. The copper shrinks rather considerably, about ¼in. to the foot, and this must be taken into consideration. The casting must be well fed and the sand mould must be rammed only very slightly. In case of iron moulds the iron must, of course, be covered with soot, and in some cases it was found desirable to use a graphite plate where the hot metal first strikes. In the case of induction rotors it was necessary to overcome difficulties due to the shrinking and cracking of the different parts of the copper casting. When these precautions are taken no more difficulty is experienced in casting copper than in casting ordinary brass. The electrical conductivity obtained can be as high as 97 per cent. of the Mathiessen standard, but in the foundry, using scrap, which is not always as clean as could be desired, we find it not feasible to guarantee more than 90 per cent. conductivity. The mechanical properties are as follows: Tensile strength, 24,350lbs.; elongation, 48·5 per cent.; elastic limit, 11,450lbs.; reduction of area, 74·49 per cent.

Proposed Bridge Across the Mersey.—A paper was recently read before the Liverpool Engineering Society by Mr. L. H. Chase, M.Inst.C.E., on "A Proposed Bridge Across the Mersey." The author suggested a suspension bridge 200ft. above high-water to clear the shipping, and a new kind of approach consisting of a reinforced concrete building looking rather like the Roman Coliseum and part of Trajan's Column. It is provided with a helical roadway for all kinds of traffic making 4½ turns. The external diameter of the roadway is 300ft., and the internal diameter 200ft. The space 200ft. diameter inside the helix is suggested to be used for office buildings lighted from the roadways and with access from a central well. The following are the chief dimensions of the proposed bridge: Main span, 2,700ft.; towers, 500ft. high, height of bridge above high water, 200ft.; depth of girders, 50ft.; weight of girders, 2,100 tons; width between girders, 50ft.; width between towers 300ft.; cables (410 sq.in. each); weight, 6,400 tons; total cost, exclusive of land and legal expenses, not exceeding £825,000. The author suggests a system of making the space between the towers wider than the girders, and making each cable hang in a plane inclined to the vertical at such an angle that the planes intersect in a line which is 20ft. vertically above the centre line of the floor of the bridge, and which is approximately the vertical centre of the wind pressure. By this method of construction the author claims that the hanging structure cannot be moved laterally as a whole. It is, however, subjected to some slight torsion due to an excess of ordinary load on one side.

STEEL CASTINGS.

AT a meeting of the Sheffield branch of the British Foundrymen's Association, held on the 17th inst., a lecture on "Steel Castings" was delivered by Mr. H. Brearley, who dealt with the subject in three sections: (1) The properties of unannealed castings; (2) the microstructural changes which steel undergoes during the annealing operation; and (3) the mechanical properties of annealed castings.

The lecturer showed by means of lantern slides and actual specimens that no distinction between castings and forgings could be based on the appearance of a fractured surface. Forgings were not always heat-treated as well as they might be, and castings after suitable heat treatment, possessed a fracture very closely akin to that of well rolled or forged steel. He also described a number of simple means which enabled one to decide whether a casting had been annealed or not, and in the former case to determine approximately the temperature at which the casting had been annealed. The use of the polished and etched surfaces for examination, either with a simple hand lens or the more elaborate outfit of technical laboratories, was highly commended.

The erratic behaviour of unannealed castings under shock stresses was shown to be due not merely to irregular cooling, which was unavoidable, but also to the size and arrangement of the crystals which made up the mass of the material, and as these were mainly dependent on the method or process by which steel was made, there were no means, nor could any be devised, whereby steel castings could be produced which were not better for being annealed. The annealing of steel used invariably to mean, and was even sometimes now taken to mean, re-heating to a uniform low red heat and slow cooling to eliminate shrinkage stresses. The insufficiency of such treatment could be seen in almost any casting made twenty years ago. But modern research had shown that the structure of a steel casting as taken from the sand could be almost entirely obliterated and replaced by a structure which was a thousand times finer and both stronger and more reliable. A series of lantern slides were shown to illustrate the scientific principles on which these transformations were based. The improved condition of a steel casting induced by annealing was not indicated by the usual form of inspection test provided for in an engineer's specification, and the lecturer advocated an impact test, which he claimed would be an all-round advantage to include in industrial specifications, because it covered the deficiencies of the present tensile and bending tests and supplied information of great value quite outside their scope.

BOOK REVIEWS.

Common Battery Telephony. Simplified by Walter Atkins. Engineering Department, G.P.O. London: "The Electrician" Publishing Company. 7½in. by 5in., 164pp. Price, 3s. net.

This little book is designed to meet the wants of practical men and students who seek plain instructions and descriptions respecting the working of modern telephonic systems. The book does not go into minute details of the apparatus employed, though the essential principles underlying the action of all such apparatus are clearly indicated and illustrated by the copious use of simple and clearly-drawn diagrams. The book, in short, is terse and practical, and no doubt will be welcomed by a large and growing class of technical men interested in this branch of applied electricity.

* * *

Notes on the Materials of Motor-car Construction, by Algernon E. Berriman, M.I.A.E., Technical Editor of the "Auto." London: Published at the offices of "Auto." Price, 5s. net.

The contents of this book consist practically of a description of the methods of manufacture adopted at the Daimler Company's works at Coventry, but though it constitutes to a large extent a "write up" of the merits of a particular firm, the matter possesses considerable intrinsic value, apart from this. It shows what great care and organising skill is exercised in up-to-date works devoted to this field of mechanical engineering, and how little British engineering firms have to learn in regard to scientific methods and equipment from Continental or American competitors.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Wet carbonising of peat. Rigby & Testrup. 19330.
Joints for flexible tubing. Hansford & Hansford. 21642.
Process of coating iron or steel with copper or alloys of copper. Rockey & Eldridge. 21661.
Means for supporting the rails of railroads and for securing them to metal sleepers. Trnka. 21793.
The purification of illuminating and coke oven gas. Davidson. 23696.
Atomisation of liquid fuel and other liquids. Dahl. 24716.
Bearing bushes. Love, and Eugéne Brown. 25914.
Construction of furnaces. Heenan & Froude, Ltd., and Leask. 26677.
Screw propellers. Le Dantec. 26722.
Packing for piston rods. Mortimer. 26827.
Aeroplanes. Alathene. 27039.
India-rubber diaphragms for pressure controlling valves. Auld. 27060.
Means for control and supply of gases and carburetted air to engines. Parker & Claudel. 27065.
Carburetters for internal-combustion engines. Albion Motor car Company and Murray. 27073.
Miner's safety lamp. Greanoff. 27085.
Alloy for use in the manufacture of iron articles which will withstand the action of acids and heating. Sefton-Jones. 27151.
Composite driving belt. Whipp. 27184.
Means for rotating shafts of machine tools. Herbert & Vernon. 27193.
Water meters or motors. Evans Cross. 27223.
Railway signalling systems. Westinghouse Brake Company and Peter. 27276.
Processes for extracting metals from ores. Mackay. 27343 and 27344.
Devices for measuring steam, gas, or liquid. Hartung. 27357.
Rotary pumps and engines. Rotoplunge Pump Company and Vincent. 27381.
Carburetters for internal-combustion engines. Edwin & Smallpage. 27398.
Clutches and a combined loose pulley and clutch. McAdams. 27501.
Automobile vehicles. Wilson. 27578.
Production of gaseous fuel. Southey. 27612.
Prime power generators known as a hydrodynamo. Howland-Shearman. 27623.
Manufacture of tapered metal tubes or pipes. Gaylor & Rankin. 27646.
Manufacture of sleeves used in roller or ball bearings for axles and shafts. Cooper. 27705.
Holder-up for riveting. Ramage. 27756.
Flying machines. Clements. 27811.
Steam superheaters. Bolton. 27899.
Flying machines. Marks. 27907.
Hermetically-sealed steam tubes for feed-water heaters. Sidey and Adams. 29240.
Power transmission means. Waud. 29382.

1912.

Apparatus for pumping water. Stevens. 274.
Mixing fans for liquid-fuel burners. Crosbie. 498.
Valves of internal-combustion engines. Drake. 565.
Variable-speed transmission mechanism. Soc. Anon. des Anciens Etablissements Panhard & Levassor. 983.
Means for casting footstep bushes or bearings for shafts. Hanna and Walker-Hanna Improved Bearings (1910), Ltd. 1041.
Rotary pumps, compressors, and engines of the fixed abutment type. Lacy-Hulbert & Co. and London. 1327.
Firebars for boiler furnaces. Holehouse. 1689.
Condensing of steam on steamships when in port. Weir. 2166.
Aeroplanes. Ponche & Primard. 2316.
Plant for the sampling of ores. Clift. 2416.
Foundry moulding machines. Smith. 2801.
Conveyers for coal-mining. Hurd. 4095.
Nut-locks. Thompson. 4391.
Motive-power plant supplying steam to auxiliary plant such as heating systems. Warwick Machinery Company (1908). 4528.
Air pumps. Fleuss. 5122.
Feed mechanism for tube rolling mills. Stuting. 5209.
Valves. Evans, Robson, & Lewis. 5233.
Welded joint for iron and steel pipes and tubes. Stewarts and Lloyds, Ltd., and Stewart. 6172.
Positive engagement clutches. Genese and Peto & Radford, Ltd. 7155.
Fitting the blades of steam turbines. Payne & Durdle. 8014.
Water-heating apparatus. Roth. 8587.
Rolling-mills with pilger or stepped rolls. Soc. Metallurgique de Montbard-Aulnoye. 8887.
Rotary steam engine. Benasso. 9175.
Blast pipes of steam locomotives. Schleyder. 9498.
Packings for rods and shafts. Meredith. 9969.
Rotary engine. Madero. 10702.
Automatically closing valves for water gauges. Rheinbach. 10933.
Liquid spraying nozzles. Robertson. 11000.
Feed water heaters. Elliott. 13145.
Welded joints for steel and iron pipes and tubes. Stewarts and Lloyds, Ltd., and Stewart. 13470.
Apparatus for generating compressed air or gas for lighting and heating purposes. "Olso" Licht Gesellschaft Halbmayr and Co. 14546.
Railway track rails. Heckmann. 14754.
Internal-combustion engines. Stoltz. 14829.
Anti-friction bearings. Brewer. 16349.
Centrifugal clutches. Robertson. 17293.
Spanners. Wetzel. 18505.
Turbine pumps. Kilburn. 19230.
Coil tube water heaters or steam generators. Reed. 20106.
Adjustable limit gauges. Moritz. 20165.
Aeroplanes. Pelterie. 21001.
Turbine pumps. Kilburn. 23360.
Roller bearings. Brewer. 23392.
Valveless lubricating pump. Muller. 25164.

ELECTRICAL, 1911.

Miner's safety lamp electric light fitting. Morrison. 28420.
Secondary or storage batteries. Clark. 29318.

1912.

Electric hand lamps. Lucas & Edwards. 3011.
Magnetic chucks. Humphreys. 6139.
Apparatus for producing electric contacts at adjustable periodic intervals. Soc. A. Granoux et Cie. 8989.
Timing devices for the electric ignition of internal-combustion engines. Robert Bosch. 12379.
Telephone repeaters. Western Electric Company. 12604.
Electric boat hoists. Sir W. G. Armstrong, Whitworth, & Co., and Wright. 12761.
Electric motor. Zabriskie. 13487.
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Fatal Winch Accident.—A serious accident occurred at the Vickers gun range at Eskmeals, Cumberland, on the 18th inst. Whilst lifting an armour-plate, an electric winch is stated to have given way, and the plate fell on several men, one of whom was killed and four others injured.

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